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A Study of Some of the Factors Affecting the Grade Relationship of Fresh and Processed Vegetables

1. CANNED TOMATOES

W. A. GOULD

R. B. DAVIS

F. A. KRANTZ, Jr.

N. C. HEALY

OHIO AGRICULTURAL EXPERIMENT STATION
WOOSTER, OHIO

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A STUDY OF SOME OF THE FACTORS AFFECTING THE GRADE RELATIONSHIP OF FRESH AND PROCESSED VEGETABLES

I. Canned Tomatoes [1, 2]

WILBUR A. GOULD, REES B. DAVIS, and FRED A. KRANTZ, Jr.
Ohio Agricultural Experiment Station
AND
NORMAN C. HEALY
Agricultural Marketing Service
U. S. Dept. of Agriculture

INTRODUCTION

In Ohio, the U. S. Standards for grades of tomatoes for canning have been used on a commercial scale since 1930 (12). Studies conducted by Hauck in 1932 (12) have indicated "that the marketing of cannery tomatoes on grade and inspection results in: (a) greater returns to growers; (b) lower labor costs and higher net returns to canners; (c) improved quality and larger volume of finished products per ton of raw stock; and (d) more equitable relationships between growers and canners."

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[1]This work was initiated in 1949 in Ohio as part of a co-operative project between the New York (Geneva), Purdue University and Ohio Agricultural Experiment Stations and the U.S.D.A. under the Agricultural Marketing Act of 1946.

[2]The authors are deeply indebted to the following personnel and wish to acknowledge their counsel and assistance for—

A. Administrative responsibilities and guidance: F. S. Howlett, H. D. Brown, V. H. Nicholson, M. W. Baker, A. E. Browne and members of the Research and Marketing Committee of the Ohio Canners Association.

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However, during the intervening seventeen years, no grade relationship studies have been reported in Ohio. The U. S. Standards for Canning Tomatoes and the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products have been widely used by both canners and growers since their issuance. Likewise, the U. S. Standards for Grades of Canned Tomatoes have been used extensively by canners and distributors of processed foods. Growers and processors, as well as officials of the U. S. Department of Agriculture, have felt for some time that accurate data should be obtained through research to show the relationship between the grades of fresh and processed tomatoes.

This research project on tomatoes, therefore, was developed with the following primary objectives:

(1) Determine quality of canned tomatoes obtained from various qualities of raw tomatoes;

(2) Study the effect of some of the factors, such as processing methods, on the grade relationship between raw and canned tomatoes; and

(3) Ascertain possible improvements in the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products, U. S. Standards for Canning Tomatoes and U. S. Standards for Grades of Canned Tomatoes in order to increase the usefulness of such grades.

REVIEW OF LITERATURE

Out of a total of 152 licensed canneries in Ohio, there are 53 plants processing canned tomatoes. Within the state, tomatoes are the leading canning crop on the basis of acreage.

Considerable work has been done on the marketing of cannery tomatoes (5, 6, 7, 8, 12, 22). Hauck stated (12) that it was believed that marketing of cannery tomatoes on grade and inspection, among other advantages, would result in improved quality. Due to marketing of cannery tomatoes on grade in the years 1949, 1950, 1951 and 1952, as shown in Chart I, the percentage of culls in all loads was less than 5 percent. This was also true of the ten year average from 1939-1948. Furthermore, this chart shows that the average grade of tomatoes received in these ten years at canneries was 64% U. S. No. 1's and 32% of U. S. No. 2's.[3, 4] The percentage of culls in the past few years are

[3]Statistical summary showing the results of the inspection of canning tomatoes at stations under Ohio jurisdiction by seasons. Bureau of Markets, Ohio Department of Agriculture.

[4]U. S. No. 1 and U. S. No. 2 quality tomatoes are defined in Table 2 and 3. A "Cull" tomato is a tomato that does not meet the requirements for a U. S. No. 2 grade tomato.

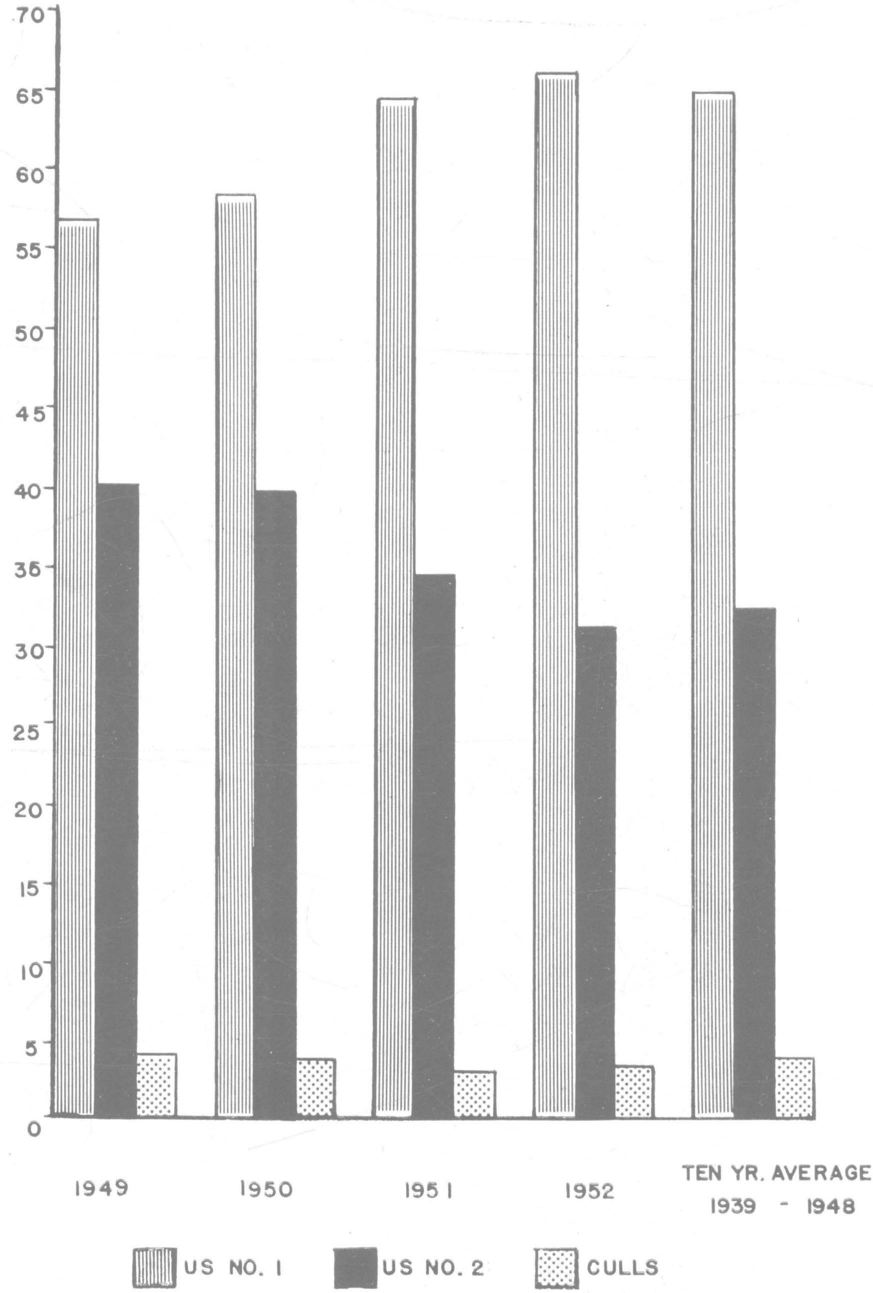

Chart I.—Average % U. S. grade of tomatoes in Ohio for years 1949 to 1953 compared to the ten year average (1939-1948).

considerably lower than the 6.8 and 12.7 percentages reported by Hauck in 1930 and 1931 respectively. However, little work has been done to show the direct correlation between raw product grade and the resulting finished product grade of canned tomatoes when using the U. S. Standards as a basis for evaluating the grades.

Fawcett et al. (4) reporting on the grade relationship of raw product grade to the grade of canned tomatoes state that "approximately 75 percent of all the off-grade (canned) tomatoes were so graded because of insufficient color, and this became more of a factor as the canning season advanced. Color as a grade factor increased from 66 percent early in the season to 87 percent in midseason and 84 percent late in the season. The number of cans of off-grade tomatoes early in the season due to drained weight, 18 percent, wholeness, 10 percent, and defects 6 percent, were reduced as the season advanced and in the overall picture wholeness and defects were never limiting factors in the canning of these tomatoes."

This report (4) also showed that it was not possible to pack a lot[5] of fancy tomatoes from U. S. High No. 1 tomatoes. In this case, all tomatoes were packed with sodium chloride and 41 cans of tomatoes out of 53 were graded fancy (77 percent); however, to obtain a lot of U. S. Grade A fancy tomatoes, 83-1/3 percent of the cans of tomatoes should have graded fancy.

With respect to processing methods, little data were available in the literature on factors affecting the quality of canned tomatoes in terms of the U. S. Standards for Grades of Canned Tomatoes.

No information was found in the literature concerning the use of the two standards available for grading the raw product; that is, the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products and the U. S. Standards for Canning Tomatoes. Many canners in Ohio packing tomatoes use the standards for strained products as well as the standards for canning without any particular research information available concerning the actual differences in terms of the quality of the finished product.

With respect to the effect of various coring methods employed in canneries, Haverkamp and Hardin (13) found that a special coring knife increased the quality of peeled tomatoes, particularly the better grades. The tomatoes were officially graded one grade higher on the average when cored with the coring knife prior to peeling when compared to conventional combined coring and peeling methods. According to their calculations a net saving of $3,065 was possible on a 20,000 case pack.

[5]"Lot" as used in this bulletin has reference to a given quantity of tomatoes.

Gould (10) has reported on the use of the Hydrout, and has pointed out some of the advantages of mechanical coring. Some Ohio tomato processors are now using the Hydrout, a water-turbine powered mechanical corer; however, little research information was available as to the effect of its use on quality.

Siegel (20) Appleman et al. (3), Le Crone et al. (20) and Kertesz et al. (15, 16, 17, 18, 19) have reported on the use and effect of calcium salts on the firming of canned tomatoes. Jacobs (14) has explained the action of the calcium salts on the firming of products like tomatoes. He states "fresh tomatoes, like all fresh fruits, contain pectic components which are relatively insoluble and which form a firm gel around the fibrous tissues of the tomato, thus preventing the collapse of the vegetable and in that way aiding in keeping it firm. When there is a breakdown of the cell structure, the pectic components are brought into contact with the enzymes of the food and the pectin is converted into pectic acid. This imparts less firmness to the tomato tissues than the original pectin, in turn causing collapse. The addition of calcium salts to tomatoes causes the formation of a calcium pectate gel which supports the tissues and protects the tomato against softening."

The Food and Drug Administration (2) has approved the use of the following salts as firming agents: purified calcium chloride, calcium sulphate, calcium citrate, mono-calcium phosphate, or any two or more of these in concentrations not to exceed 0.026 percent calcium by weight in the finished canned tomatoes. Added calcium salts must be properly declared on the label.

According to Kertesz et al. (17) the addition of calcium salts to tomatoes during canning improved the wholeness and drained weight of the canned tomatoes. The results on drained weight given by Kertesz et al. (17) in terms of percentage of can capacity were appropriately converted to drained weight scores according to the U. S. Department of Agriculture Standards for Grades of Canned Tomatoes, (1). When kept within the .026 percent allowance for calcium, their results showed that in two out of three replicates, the score for drained weight was raised from Grade C to Grade A. However, their results were not interpreted in terms of the grade of the raw product or in terms of USDA Standards for Grades of Canned Tomatoes. No data were given on the effect of added calcium salts on other factors of quality for canned tomatoes.

EXPERIMENTAL METHODS

Varieties

Research work was started during the 1949 tomato canning season and continued through the 1952 season. In 1949, 1950, and 1951, two varieties, Rutgers and Stokesdale, were used. In 1952, only the Rutgers variety was used. In 1949, the plants grew at the Northwest Test Farm of the Ohio Agricultural Experiment Station at Holgate, Ohio while in 1950, 1951, and 1952, the tomatoes grew on the Horticultural Farm at Ohio State University, Columbus, Ohio.

Growing Practices

During all four year the tomatoes grew in accordance with acceptable commercial practice for production of canning tomatoes in Ohio. In 1949, the tomatoes grew on Paulding clay soil with 200 pounds of cyanamid and 800 pounds of 0-12-12 fertilizer plowed down. In 1950, 1951, and 1952, the tomatoes grew on a silt loam soil, with green manure crop (rye) plowed down prior to planting. In 1950, the tomato field received approximately twenty tons of manure per acre. In 1950, 1951, and 1952, 1000 pounds of 5-10-10 fertilizer was disked in at the time of fitting the soil approximately two weeks before planting date. In all four years the tomato seed was started in flats in the greenhouse, the plants were conditioned in cold frames and transplanted in the field as soon as danger of the last killing frost had passed. No starter solution was used at the time of transplanting, but in 1950, 1951, and 1952, the plants were irrigated immediately after transplanting.

At seven to ten-day intervals throughout the growing season, up to harvest time, the plants were sprayed with fixed copper alternating with Ziram (Zerlate) to control early blight, late blight, and anthracnose. The plants were dusted with purified (Aerosol grade) DDT to control flea beetles and sprayed with Malathion for aphid control.

Harvesting was started when the fruits were ripe enough to comply with the quality desired for processing in the pilot plant (Table 1). The first picking of both varieties was started on September 2 in 1949 and ended on September 30. In 1950, the picking of the Stokesdale variety was started on August 28 and finished September 16; the picking of the Rutgers variety was started August 28 and finished September 26. In 1951 the picking was started on August 9 for the Stokesdale variety and finished on August 29; the picking of the Rutgers variety was started on August 13 and finished September 18. In 1952 picking of the Rutgers variety was started on August 19 and finished on September 25. Harvesting was continued at weekly intervals until the tomatoes became too small in size to be handled by the processing machinery or until the plants and fruits were killed by frost.

TABLE 1.—Composition of Experimental Lots of Raw Tomatoes for Processing into Canned Tomatoes

Experimental Lot No.	Percent No. 1's		Percent No. 2's		Percent Cull
	Color	Defects	Color	Defects	
1	100	—	—	—	—
2	90	—	10	—	—
3	75	—	25	—	—
4	75	—	15	10	—
5	60	—	35	5	—
6	60	—	25	15	—
7	45	—	35	20	—
8	35	—	65	—	—
9	100 High # 1's	—	—	—	—
10	100 Low # 1's	—	—	—	—
11	—	—	100 High # 2's	—	—
12	—	—	100 Low # 2's	—	—
13	75	—	—	25	—
14	35	—	—	65	—
15	—	—	100	—	—
30 (Field Run)	34	—	46	20	—

Raw Products Grading

Prior to processing, the fresh tomatoes were graded by an official inspector (a different inspector was used each year) of the Federal-State Fruit & Vegetable Inspection Service. Each tomato was graded and segregated individually according to the factors of color and defects as outlined in the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products (Table 2).

Due to the fact that many Ohio tomato canners, packing canned tomatoes, buy their raw product on the basis of the grade standards for strained tomato products, and since tomato juice, tomato pulp, and tomatoes were being packed simultaneously at the pilot plant, it was believed that grading the raw product according to these standards would represent commercial practices in the state as well as to simplify the experimental procedure at the pilot plant. In 1952, a portion of the raw tomatoes was graded and segregated on the basis of the U. S. Standards for Canning Tomatoes (Table 3) and another portion on the basis of the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products (Table 2).

TABLE 2.—U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products, March 1, 1933‡

Factors	U. S. No. 1	U. S. No. 2
Color	"Well colored". 90% of flesh has good red color.	"Fairly well colored". 66-2/3% of flesh has good red color.
Firmness	Fairly firm (means not water soaked, might be soft, shriveled, or puffy; provided it isn't tough or rubbery).	No requirement. Tomatoes can only be scored as culls from the standpoint of losing more than 20% in the washing process, provided they are not shriveled to the extent that they have become tough and rubbery.
Stems	Not permitted, (except when the canner wishes to permit stems. In such cases it can be handled by a statement preceding No. 1 Grade. Thus: "Except for stems U. S. No. 1").	Permitted.
Decay or Mold	Molds or very slight decay permitted provided it can be washed out in the ordinary process of washing without hand trimming.	Permitted, provided the tomato is not sour and it can be removed in the ordinary process of trimming without a loss of more than 20% by weight of the tomato.
Sunburn, Sunscald, Growth Cracks, Catfaces, Freezing Injury	*Free from damage.	†Free from serious damage.
Worms and Worm Injury	Worms or worm injury that has penetrated beneath the outer wall of the tomato not permitted.	Same as U. S. No. 1.
Shape	There are no shape requirements.	No requirements.
Size	There are no size requirements.	No requirements.

*"Damage" means any injury, defect, or their combination which cannot be removed in the ordinary process of trimming and peeling without a loss of more than 10% (by weight) of the tomato in excess of that which would occur if the tomato were perfect.

†"Serious damage" means any injury, defect, or their combination which cannot be removed in the ordinary process of trimming and peeling without a loss of more than 20% (by weight) of the tomato in excess of that which would occur if the tomato were perfect.

NOTE—Cull tomatoes are tomatoes that fail to meet the requirements of either U. S. No. 1 or U. S. No. 2 tomatoes.

‡Issued by the U. S. Department of Agriculture.

TABLE 3.—U. S. Standards for Canning Tomatoes (December 15, 1938)‡

Factors	U. S. No. 1	U. S. No. 2
Color	"Well colored". 90% of flesh has good red rolor.	"Fairly well colored". 66-2/3 % of flesh has good color.
Firmness	Firm (means not soft, puffy, shriveled or water soaked).	No requirement. However, if the tomato is soft enough to break down in the ordinary process of trimming and washing, thereby causing a loss of more than 20% it should be classified as a cull from the standpoint of waste.
Stems	Permitted.	Permitted.
Decay or mold	None.	Permitted, provided it can be removed in the ordinary process of hand trimming or washing, without a greater loss than 20% by weight of the tomato.
Sunburn, Sunscald, Growth Cracks, Catfaces, Freezing Injury	*Free from damage.	†Free from serious damage.
Worms and Worm Injury	*Free from damage.	†Free from serious damage.
Shape	Well formed (means that the tomato shall not be extremely flat or otherwise badly misshapen.)	No requirement.
Size	The **Minimum Size** may be fixed by agreement between buyer and seller. Tomatoes below this specified minimum size shall be classed as culls.	Same as U. S. No. 1.

*"Damage" means any injury, defect, or their combination which cannot be removed in the ordinary process of trimming and peeling without a loss of more than 10% (by weight) of the tomato in excess of that which would occur if the tomato were perfect.

†"Serious damage" means any injury, defect or their combination which cannot be removed in the ordinary process of trimming and peeling without a loss of more than 20% (by weight) of the tomato in excess of that which would occur if the tomato were perfect.

NOTE—Cull tomatoes are tomatoes that fail to meet the requirements of either U. S. No. 1 or U. S. No. 2 tomatoes.

‡Issued by U. S. Department of Agriculture.

A grading table shaded from direct sunlight was provided outside the tomato processing pilot plant at Ohio State University. The official inspector handled each fruit individually and segregated the tomatoes into four grades as follows:

(1) U. S. No. 1;
(2) U. S. No. 2 for color (U. S. No. 1 for defects);
(3) U. S. No. 2 for defects (U. S. No. 1 for color); and
(4) Culls.

For certain lots the inspector further distinguished between U. S. No. 1's for color by separating them into lots designated as **high** U. S. No. 1's for color and **low** U. S. No. 1's for color. Likewise, the U. S. No. 2's for color were separated into **high** U. S. No. 2's (80 percent good red color up to 90 percent good red color) and **low** U. S. No. 2's (66-2/3 good red color up to 80 percent good red color) for color.

Tomatoes graded and sorted by the grader were recombined in lots of definite percentages (Table 1) and processed usually within two hours after grading.

Quantity Packed

A total of 142 lots (approximately 6000 cans) of canned tomatoes were processed during the four years; 36 lots in 1949; 54 lots in 1950; 28 lots in 1951; and 24 lots in 1952.

Processing Methods

A flow diagram of the canned tomato operations is shown in Figure 1. The specific steps in the pilot plant processing of tomatoes are discussed below.

Two 50-pound duplicates of each lot were prepared simultaneously. During processing, the tomatoes from one of these 50-pound duplicates were peeled and packed in cans. The other 50-pound lot was made into juice to be used as the packing medium for the canned tomatoes.

The fifty pounds of tomatoes for peeling were placed in an air-agitated washer for three to five minutes, then conveyed on a roller type washer which elevated the tomatoes up under a 120- to 130-pound high pressure water spray. Each tomato was subjected to the equivalent of two revolutions while being washed under the high pressure spray. The tomatoes were then scalded by conveying them through a live steam scald box for forty to fifty seconds, depending on the grade of raw product. The tomatoes were then conveyed onto the continuous trimming and packing belt. During 1949, 1950 and 1951 tomatoes were cored with a Mark Lowe tomato coring spoon and then hand-peeled

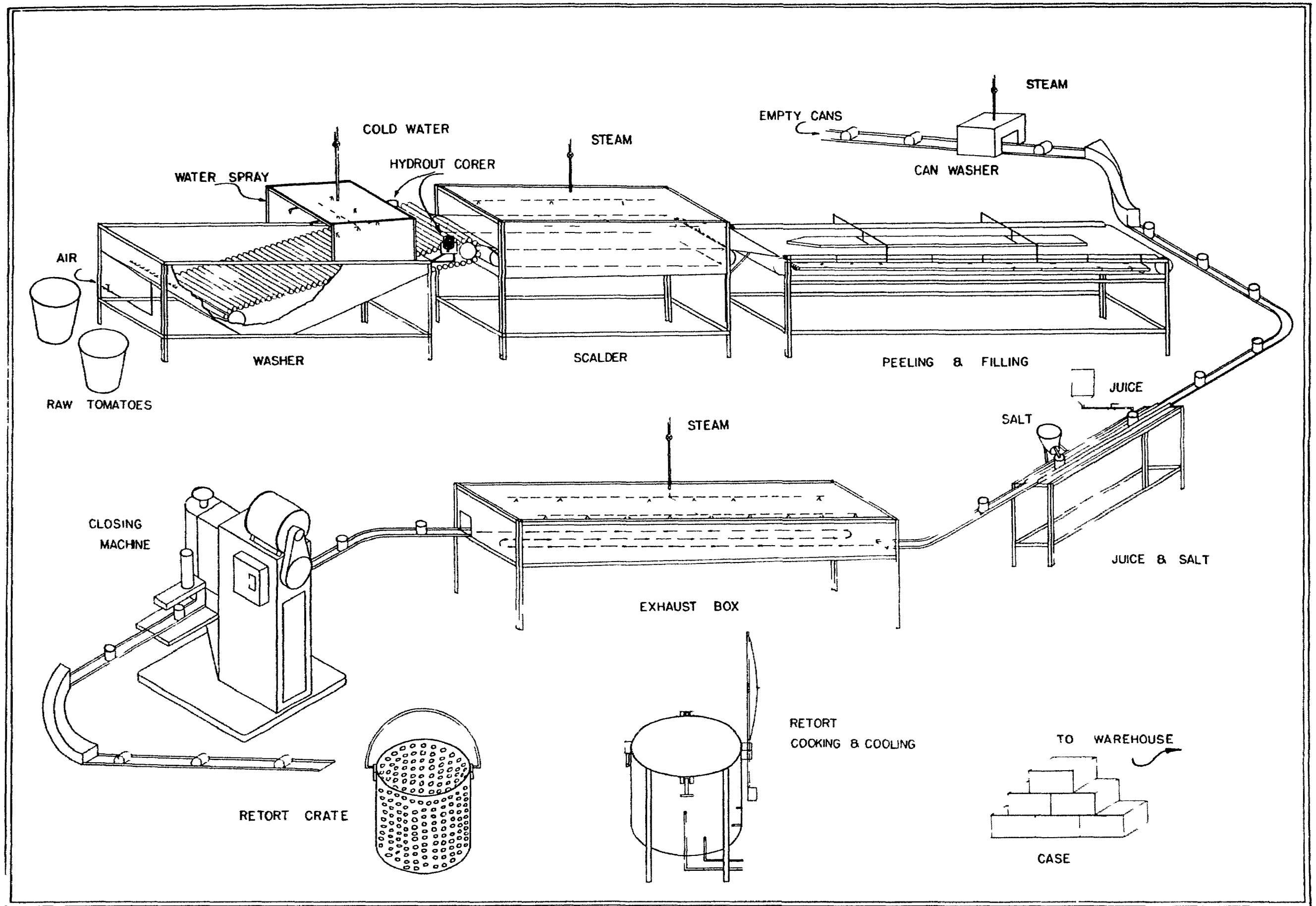

Fig. 1.—Flow sheet for canning of tomatoes.

and trimmed with a Smiley tomato knife. In 1952, the tomatoes were cored with the Hydrout tomato corer (Fig. 2).[6] The tomatoes were cored after washing and prior to scalding when using the Hydrout.

Peeled tomatoes were then placed in the center of the divided trimming belt and were hand packed into No. 2 plain tin cans. The cans had been previously steam sterilized. A thirty grain salt (sodium chloride) tablet was added to each can. In 1949, 1950 and 1951 most of the peeled and trimmed tomatoes were packed into the cans without any segregation as to the anticipated grade of the finished product and the cans were filled as full as practicable. Certain lots of tomatoes in 1949 and 1950 were peeled, trimmed, sorted, and packed, in an attempt to obtain fancy, extra-standard and standard grades in the canned

[6]Hydrout used in these studies manufactured by Magnuson Engineers, San Jose, California. (Blade No. 10378 was used in these studies).

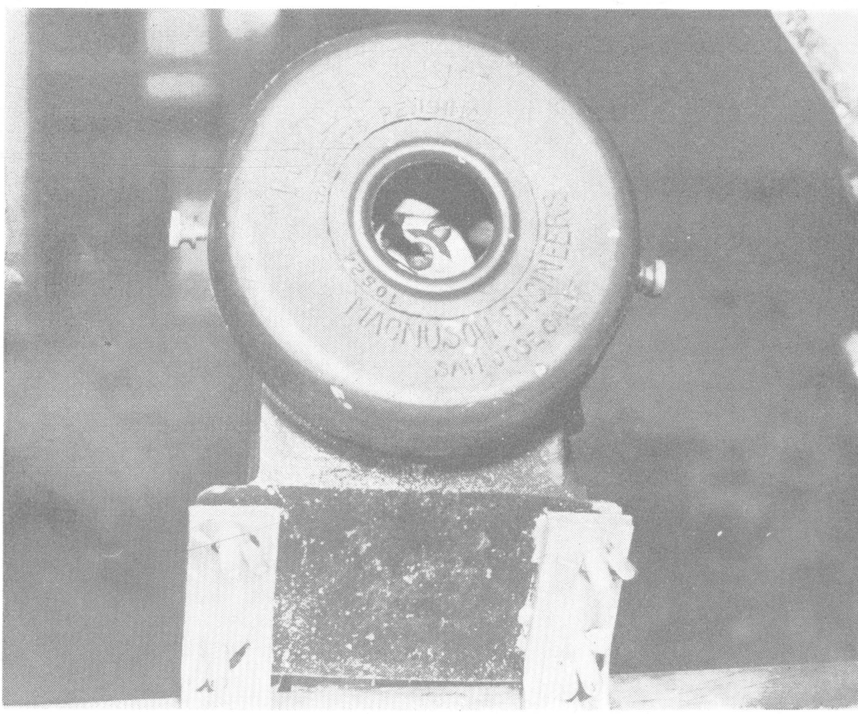

Fig. 2.—Hydrout tomato corer used in 1952 tests.

product. These lots are designated as "packed for grade" (Process 4); whereas all the other lots were packed into cans without any segregation as to the anticipated grade of the canned product, and they are designated as "mine-run" (Process 3). Peeling and trimming wastes were collected for each lot and weighed. Yields were determined from the number of cans packed from each lot of raw tomatoes, although no record was kept of the amount of juice used from the 50-pound lot used as filling medium.

During the 1952 season several lots of tomatoes were canned with calcium chloride-sodium chloride salt tablets (hereinafter referred to as calcium chloride salt tablet) in addition to those packed with the plain sodium chloride salt tablets.

The tomato juice for the packing medium was prepared by washing 50 pounds of tomatoes of a lot of similar composition as described previously and cold-extracted in a Langsenkamp Model B Extractor with a screen of .023-inch openings. The juice prepared in this manner was then used to fill the cans in which the peeled and trimmed tomatoes had been packed.

The tomatoes were then exhausted in an A. K. Robbins Continuous Exhaust Box for 4½ minutes, using live steam. A center can temperature of 100-110° F. was reached in this exhaust box. Immediately after exhausting, the cans were sealed with an American Can Company (006) closing machine. Figure 3. After sealing, the cans were placed in a retort crate (150 No. 2 can capacity) and processed at 1 to 2 pounds steam pressure (214° F. – 216° F.) for 30 minutes. Process time and temperature were automatically controlled and recorded by means of a Foxboro Recording Instrument. After processing, the tomatoes were cooled in the retort with cold water to approximately 100° F. by continuously running water in from the bottom to the top in the retort. The finished product was then held approximately six weeks at room temperature until graded.

The canned tomatoes processed from lots of varying compositions as outlined in Table 1 were graded in accordance with the U. S. Standards for Grades of Canned Tomatoes (Table 4) by one official inspector in 1949 and two official inspectors in 1950, 1951, and 1952, from the Processed Products Standardization and Inspection Branch, Fruit and Vegetable Division, Agricultural Marketing Service of the U. S. Department of Agriculture. Canned tomatoes were graded according to the grade factors in the U. S. Standards for Grades of Canned Tomatoes as given in Table 4.

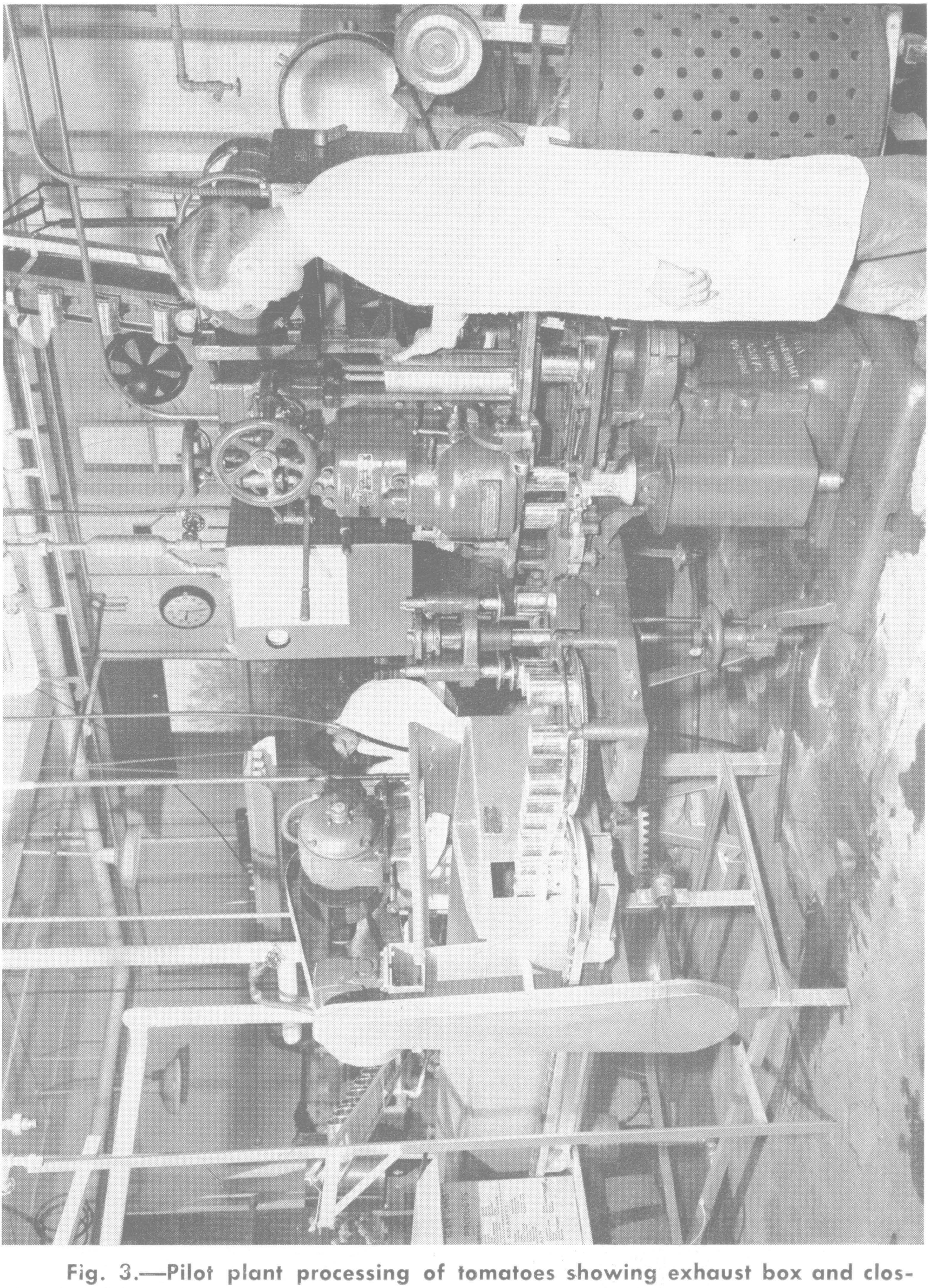

Fig. 3.—Pilot plant processing of tomatoes showing exhaust box and closing machine.

TABLE 4.—U. S. Standards for Grades of Canned Tomatoes.†
(August 1, 1946)

Factors of Grades	Score Points by Grades			
	U. S. Grade A	U. S. Grade B	U. S. Grade C	U. S. Grade D
Drained weight	18–20	15–17*	12–14*	0–11*
Wholeness	18–20	15–17	12–14*	0–11*
Color	27–30	23–26*	19–22*	0–18*
Absence of defects	27–30	22–26*	17–21*	0–16*

*Indicates limiting rule within classification.
†Issued by U S Department of Agriculture

EXPERIMENTAL RESULTS

The results of this grade relationship study on canned tomatoes are presented by considering five major factors that were believed to have an effect on the grade relationship. These are: (A) effect of standard used in grading raw tomatoes for canning; (B) effect of the quality of the raw product on the grade of the finished product; (C) effect of season on color and drained weight scores of canned tomatoes; (D) effect of variety on color and drained weight scores of canned tomatoes; and (E) effect of processing methods on drained weights of canned tomatoes. Where possible, the data for each of these factors are summarized and presented graphically in the following sections. The detailed data are presented in Appendix I with the climatological data presented in Appendix II. In addition to the above, the relationships of yield of canned tomatoes from different grades of raw tomatoes are presented in section (F) of the discussion.

A. Effect of Standard Used in Grading Tomatoes

In an attempt to evaluate one of the variables believed to affect the grade relationship of raw product to finished product, an experiment was designed using Rutgers variety of tomatoes graded in accordance with the two raw product standards (1) "U. S. Standards for Canning Tomatoes" and (2) "U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products", as given in Table 2 and Table 3. For this experiment, only those tomatoes which met specifications for U. S. No. 1 grade were used. This experiment was replicated three times during the 1952 season. In Table 5, the data are presented to show the effect of the two types of standards employed in grading the raw product on the various factors of grade used in evaluating the quality of the canned product. Further in Table 5, statistical data[7] are presented for interpreting the data obtained.

The data in Table 5 and Chart II clearly indicate that there was no significant difference between the two raw product standards used as to their effect on the grade factors for canned tomatoes. These data indicate that a tomato processor can grade his raw product in accordance with either raw product standard and expect to find little or no difference in the factors of grade for canned tomatoes. It should be pointed out while discussing these data that the grade factor of drained weight for canned tomatoes had greater coefficients of variability than was found for all other factors of grades. This will be discussed in detail under processing variables affecting drained weights of canned tomatoes (Section E).

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[7]For the reader not familiar with the statistical terminology as used in these tables, the following statements are presented (more detailed information is available from books such as: A. V. Feigenbaum's "Quality Control; Principles, Practice and Administration," McGraw-Hill Book Co., Inc., New York (1951); E. L. Grant's "Statistical Quality Control," McGraw-Hill Book Co., Inc., New York (1946); and others dealing with the use of statistics in quality control):

Average values ($\bar{X}$) were calculated by totaling each of the individual observations (score for individual factors) and dividing by the total number of observations.

Standard deviation (σ) was calculated by taking the root-mean square of the deviations (d) of individual observations from the average ($\bar{X}$). Thus: $\sigma = \sqrt{\frac{S(d^2)}{n}}$

Mean square of the error (σ_x) was calculated by dividing the standard deviation (σ) by the square root of the number of observations (n). Thus: $\sigma_x = \sigma/\sqrt{n}$.

The coefficient of variability (V) was calculated by dividing the standard deviation (σ) by the mean ($\bar{X}$) and then multiplying by 100. Thus: $V = \frac{\sigma}{\bar{X}} \times 100$.

This is a measure of relative dispersion of any two values determined for the same score factors.

1.96 multiplied by sigma (σ) is the plus or minus deviation from the mean within which range 95% of the observations are included.

TABLE 5.—Effect of Standard Used to Grade Raw Product on Quality of Canned Tomatoes. (All Lots 100% U. S. No. 1 Tomatoes—288 Cans Evaluated for Each Standard Used.) (1952 Season)

Processed grade factors	Standard used-raw	Average value's $\bar{X}$	Standard deviation σ	Mean square of error $\sigma_{\bar{x}}$	95% ± values $1.96\,\sigma$	Coefficient of variability V
Total score	Strained	93.13	2.56	0.151	5.02	2.74
	Canning	92.91	2.82	0.166	5.53	3.04
Drained weight	Strained	18.04	1.44	0.144	3.80	10.75
	Canning	17.60	1.89	0.111	3.70	10.74
Color	Strained	27.99	1.27	0.075	2.49	4.54
	Canning	28.22	1.21	0.071	2.37	4.29
Wholeness	Strained	17.64	0.67	0 039	1.31	3.80
	Canning	17.67	0.68	0.040	1.33	3.85
Defects	Strained	29.56	0.97	0.057	1.89	3.30
	Canning	29.40	1.03	0.061	2.02	3.50

B. Effect of Grade of Raw Product on Grade of Finished Product

The data presented in Chart III give the overall average grades for all lots of canned tomatoes processed for the three years (1949, 1950, and 1951) and two varieties (Rutgers and Stokesdale). It can be seen that there was a definite relationship between raw product grade and the grade of the processed product. Lots of 100 percent No. 1 tomatoes produced canned tomatoes which graded 47 percent Grade A, 43 percent Grade B, 9 percent Grade C and 1 percent Grade D. Contrasting this to lot 8 (35 percent 1's and 65 percent 2's for color) which produced canned tomatoes which graded 18 percent Grade A, 60 percent Grade B, 21 percent Grade C and 1 percent Grade D, it can be seen that 82 percent of the canned tomatoes in the latter case graded Grade B or lower whereas only 53 percent were Grade B or lower in the lot of 100 percent No. 1 tomatoes. It should be pointed out that up to the point where there were less than 45 percent U. S. No. 1's and/or more than 20 percent U. S. No. 2's for defects, the percentage of cans grading Grade B or better was above 86 percent. This means that according to the present U. S. grade requirements, the lot would be Grade B since the tolerance is one container out of six, providing none of the containers fall more than 4 points below the minimum score of the grade as indicated by the average score.[8]

[8]Tolerances for Certification of Officially Drawn Samples. U. S Standards for Grades of Canned Tomatoes.

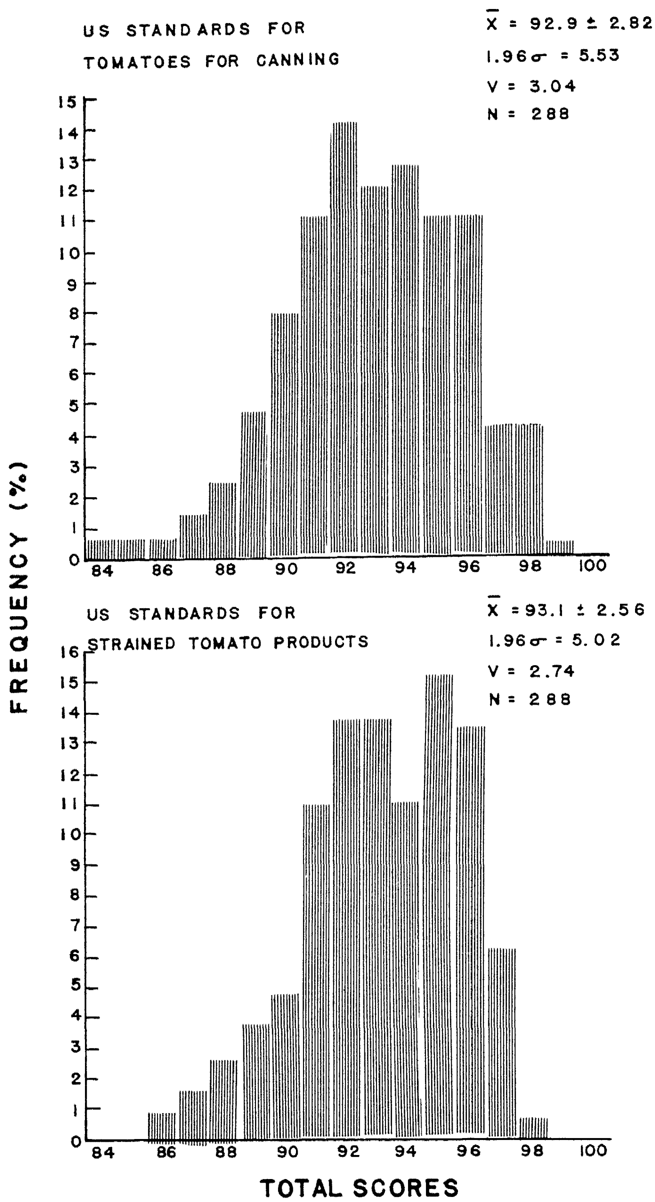


Chart II.—Frequency distribution curves for total scores for canned tomatoes graded on different raw product standards.

These data also show that when the raw product is lower in quality than 45 percent U. S. No. 1's and/or over 20 percent U. S. No. 2's for defects, less than 22 percent Grade A canned tomatoes can be realized

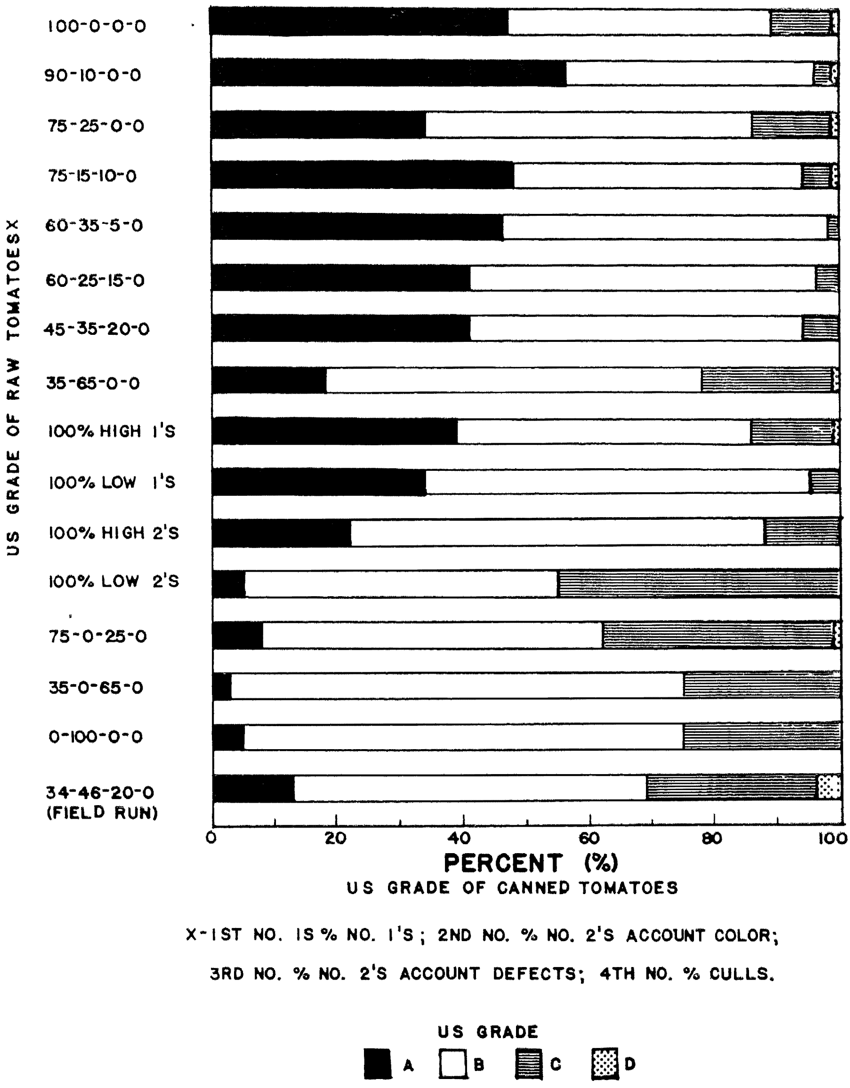


Chart III.—Grade relationship of canned tomatoes by raw product grade (lots) disregarding year and variety.

by packing for grade. In these cases from 21 percent to 45 percent of the tomatoes were graded Grade C due primarily to color and drained weights as will be discussed below.

The data presented in Chart IV give the average grade by score points assigned each factor of quality as given in Table 4 for all lots of canned tomatoes processed for the three years (1949, 1950, 1951) and of the two varieties (Rutgers and Stokesdale). The information presented in this table shows that when the raw product lot consisted of 90 percent U. S. No. 1's or better, a Grade A finished product was obtained, with the following exceptions: 100 percent High and 100 percent Low U. S. No. 1's as packed in 1951 did not produce a fancy product. The reason for this may have been that the tomatoes, after canning, were too soft to score in the Grade A range on account of low drained weight scores in the case of the 100 percent High U. S. No. 1 lots. Furthermore, the 100 percent Low U. S. No. 1 lot (tomatoes 90-95 percent good red color) did not meet Grade A requirements for color.

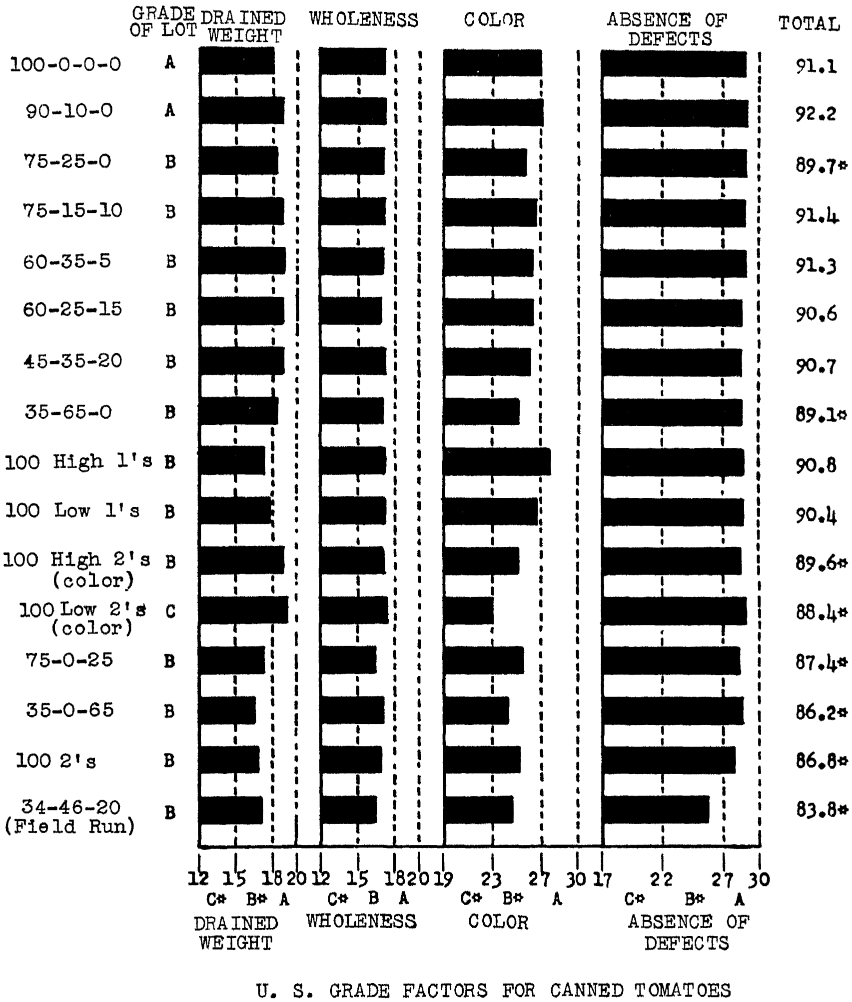
Tomatoes which had a raw product composition of 75 percent U. S. No. 1's or less, did not produce canned tomatoes of Grade A color when considering the over-all average grade of the finished product.

The only case where the over-all average grade of the finished product for the lot scored in the Grade C range was the 100 percent Low, U. S. No. 2 lot, which was scored Grade C because of poor color. It should be noted that these tomatoes produced the highest drained weight and wholeness scores in the canned product of any lot of tomatoes processed.

Canned tomatoes packed from the lots containing a high percentage of defects scored in the Grade B range on account of both color and drained weight. The low drained weight was probably due to the necessity of trimming the defective tomatoes in preparing them for canning. Also, tomatoes with a high percentage of defects in the original raw product were graded lowest for the factor of wholeness due to the amount of trimming required.

As to the effect of the raw product grade on the score for absence of defects in the finished product, there were no differences between the lots, with the exception of the field run lot. This would be expected since the factor of absence of defects is a measure of the efficiency of workmanship; and under these pilot plant conditions, careful supervision of labor and practice of good quality control techniques were exercised at all times.

As shown in Chart IV, the wholeness factor of grade of canned tomatoes for all lots processed was scored in the Grade B classification. These data indicate that wholeness was not directly related to raw product grade requirements, at least, when using these pilot plant processing techniques and varieties. Therefore, from this study, the two



* Indicates limiting rule within classification.

Chart IV.—Average scores by lots of total cans cut of canned tomatoes by lots disregarding year, variety and whether pre-graded or mine run.

factors of grade in the canned product that appeared to be of most importance in the grade relationship of the raw tomatoes to the canned tomatoes were **color** and **drained weight.**

In Chart V, the frequency distribution curves are presented for color and drained weight scores of canned tomatoes for Lot 1 (100 percent No. 1's) and Lot 3 (75-25-0) disregarding variety and year. These data show a lower coefficient of variability (V) when comparing Lot 1 to Lot 3 for color and conversely, a lower coefficient of variability when comparing Lot 3 to Lot 1 for drained weights. These data indicate that lots of tomatoes with high color in the raw product (100 percent No. 1's), compared with lots of tomatoes with average color (75-25-0), packed out with a significantly higher average color score and less variation in color scores as measured by the coefficient of variability. Further, the high color tomatoes in the raw product packed out with a significantly lower average drained weight scores and greater variation in drained weight scores in the canned product.

In Chart VI are shown the results obtained by packing tomatoes with a raw product composition of 100 percent High No. 1's (Lot 9), 100 percent Low No. 1's (Lot 10) and 100 percent High No. 2's (Lot 11). The average scores for color and drained weight and the coefficients of variability fell between those obtained for Lot 9 and Lot 11 as cited above. These data are conclusive evidence that a tomato packer must have highly colored tomatoes (No. 1's) in order to meet Grade A requirements for USDA color scores of canned tomatoes. However, these data also point out that, when using the Rutgers variety of tomatoes and processing as previously described, the canned tomatoes will have average USDA drained weight scores in the Grade B classification and a greater variation in the drained weight scores if using high quality (High U. S. No. 1) tomatoes.

These above statements are accentuated when using tomatoes with a raw product grade of 100 percent High No. 1's (Lot 9) versus tomatoes with a raw product grade of 100 percent High No. 2's (Lot 11). These data are shown in Chart VI. The average score for color in the lot of 100 percent High No. 1's is 27.70 ± 1.11 with a coefficient of variability of 4.01. This can be contrasted to the 100 percent High No. 2 lot with an average color score of 24.07 ± 2.09 and with a coefficient of variability of 8.68. As to drained weight scores, the reverse situation is shown in Chart VI. In this case, the 100 percent High No. 1 lot had an average score of 17.15 ± 2.25 and a coefficient of variability of 13.12 when compared to the 100 percent High No. 2 lots having an average score of 18.32 ± 1.74 with a coefficient of variability of 9.50.

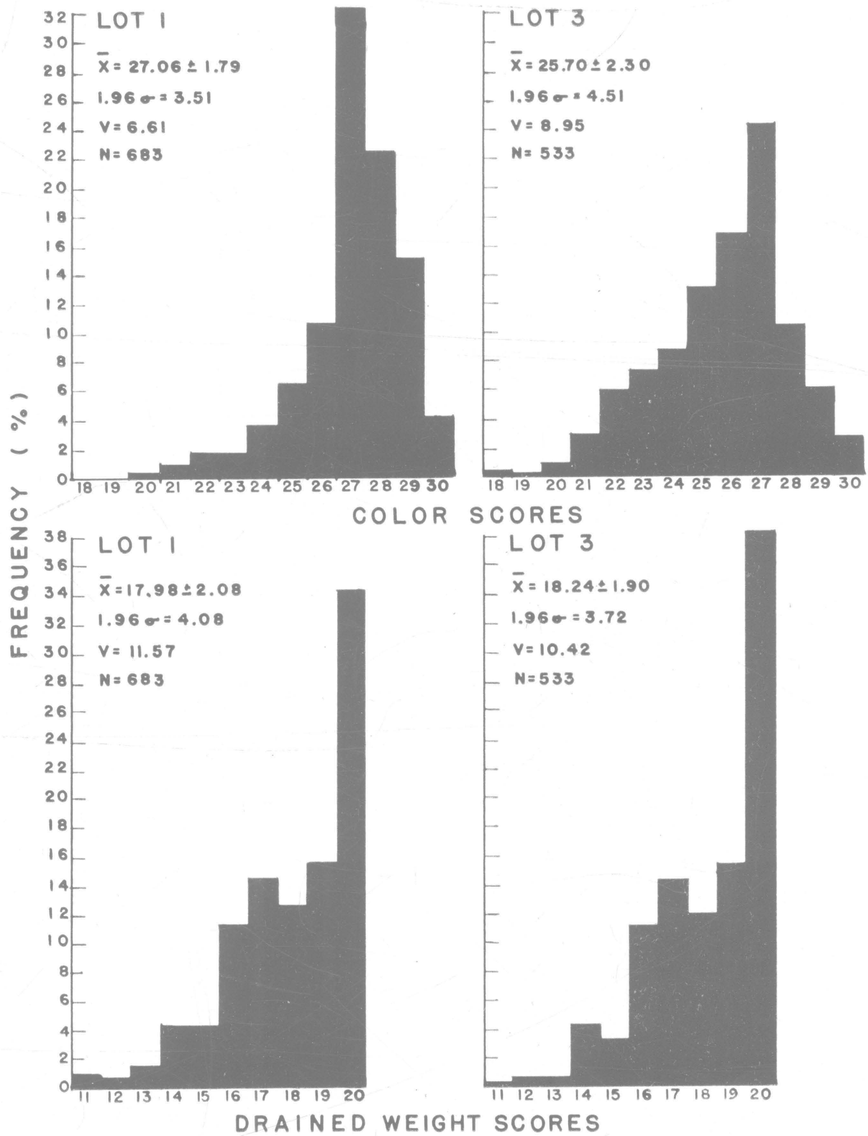


Chart V.—Frequency distribution of color and drained weight scores of canned tomatoes by Lot 1 (100% No. 1's) and Lot 3 (75-25-0) disregarding variety and year.

Thus, it can be seen from the data presented in Chart V and VI, that the tomato packer must have high quality raw products to meet Grade A color requirements in the canned product. Further, in order

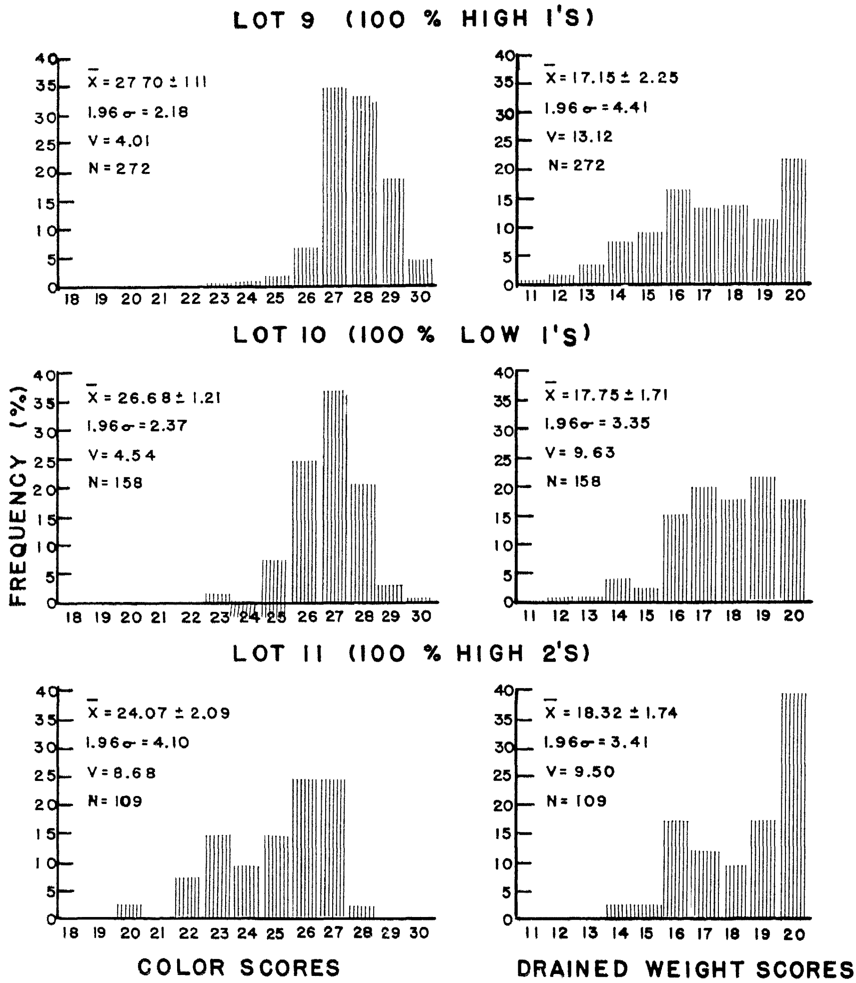


Chart VI.—Frequency distribution of color and drained weight scores of canned tomatoes for the variety Rutgers (1951).

to meet USDA drained weight requirements for Grade A canned tomatoes when using a high quality raw product for color, certain processing techniques must be resorted to. These will be discussed under Section E of this bulletin.

C. Effect of Season on Drained Weight and Color Scores of Canned Tomatoes

Charts VII and VIII illustrate the color and drained weight scores of canned tomatoes by year (1949, 1950, and 1951), disregarding variety for Lot 1 (100 percent No. 1's and Lot 3 (75-25-0) respectively. Considerable variation existed for the drained weight scores among the three years. In 1951, tomatoes packed from the same quality of raw tomatoes had considerably lower drained weight scores with relatively high variation when comparing the coefficients of variability for the three years. On the other hand, the 1949 and 1950 seasons were nearly comparable as to average scores and variations for Lot 3 (Chart VIII). Lot No. 1, however, had higher average drained weights in 1950 with less variation than was found in 1949. Although the 1949 average score value for drained weights was considerably higher than the 1951 average score value, the variation was only slightly greater than that found in 1951. Weather data were not available for 1949; however, in 1950 and 1951 the climatological data presented in Appendix II show the 1950 growing season as having an almost normal temperature with a practically normal rainfall during the months of July and August. Whereas, during the 1951 season, the temperature was considerably higher than normal, with about the same average deficiency in rainfall as in 1950. It should be pointed out, however, that during the later stages of plant growth and maturing of the tomatoes in the field, a deficiency of 2.7 inches of rain in July and 3 inches of rain in August was noted for 1951. This deficiency in rainfall and high temperature could explain in part the variation found in 1951 as contrasted to the 1950 season.

In Charts VII and VIII, the average color scores of the canned product show little variation within a given lot for the three years. There was some variation in the coefficients of variability for each of the lots and among the years. However, no conclusive statements can be drawn with respect to the effect of season variations in color scores within a lot when disregarding the factor of variety.

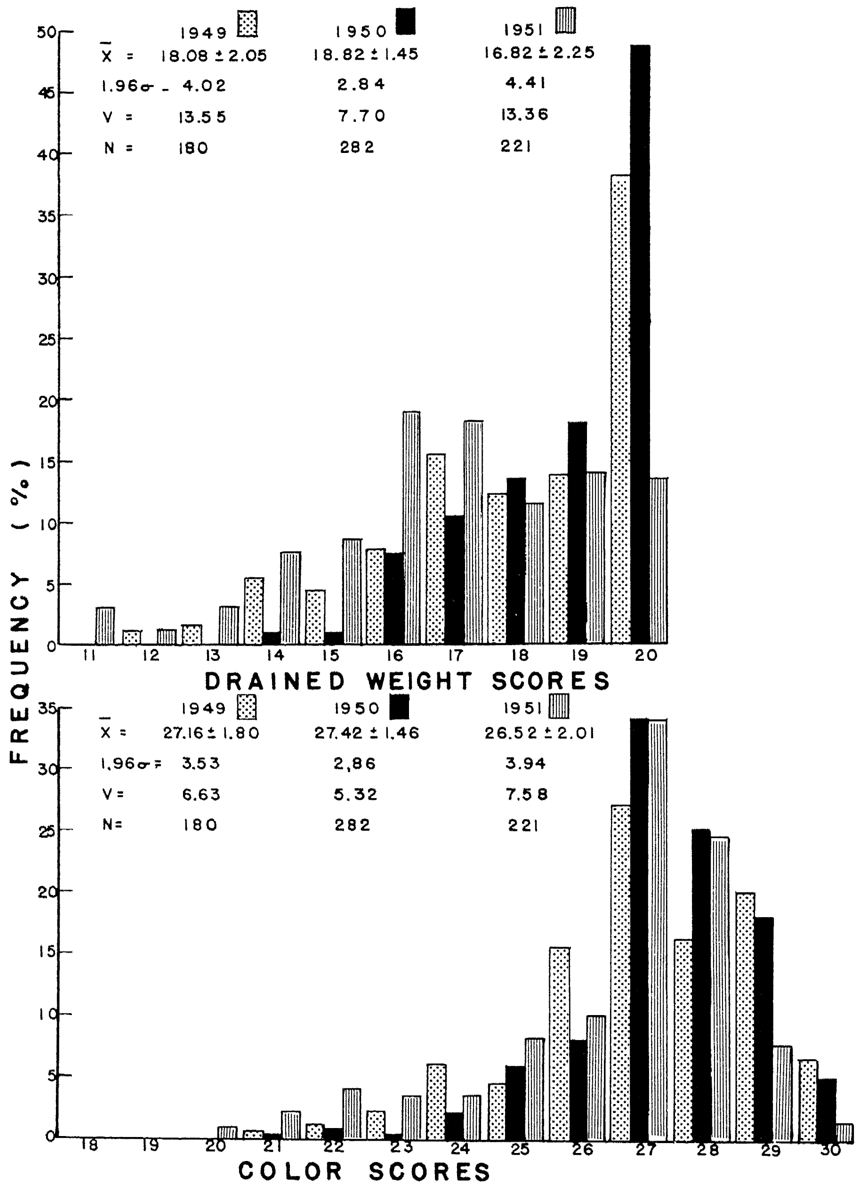


Chart VII.—Frequency distribution of color and drained weight scores of canned tomatoes by year disregarding variety (Lot 1—100% No. 1's).

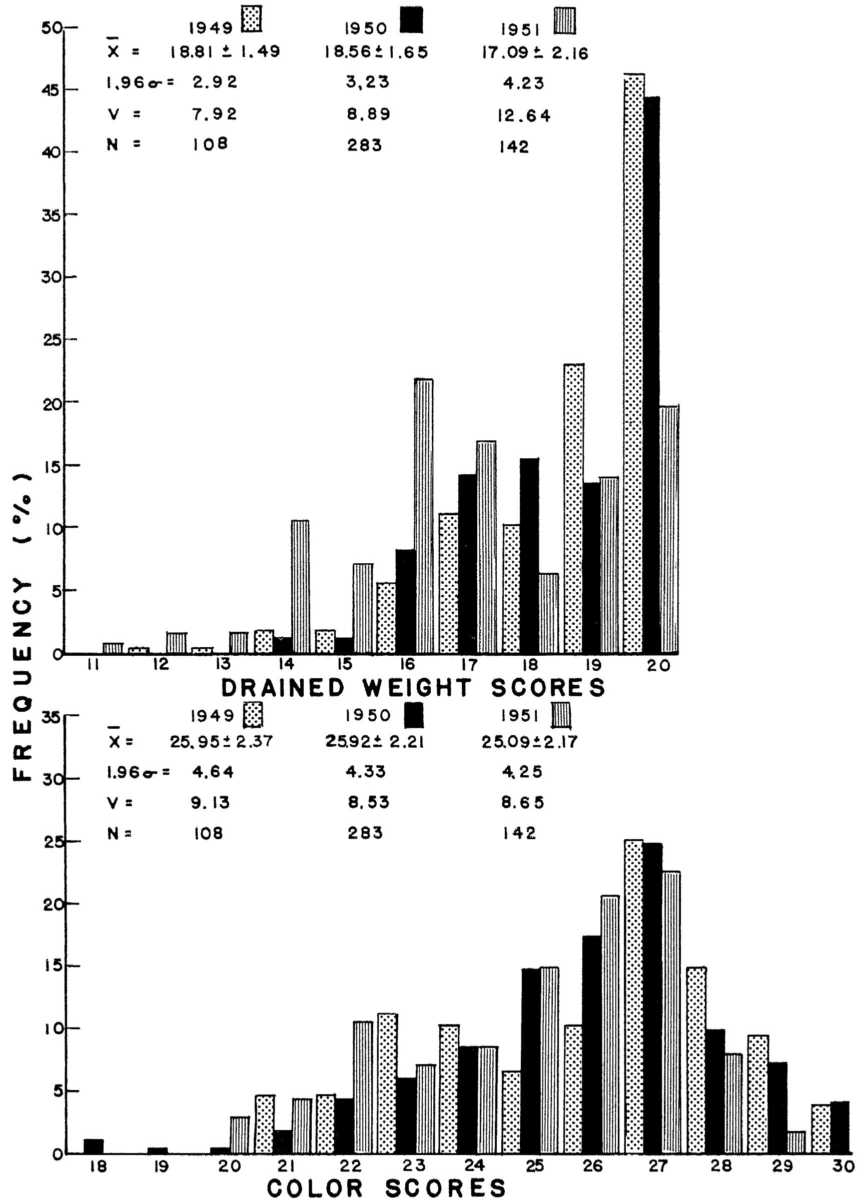


Chart VIII.—Frequency distribution of color and drained weight scores of canned tomatoes by year disregarding variety (Lot 3—75-25-0).

D. Effect of Variety on Drained Weights and Color Scores of Canned Tomatoes

Chart IX and X present the drained weight and color scores respectively of canned tomatoes by variety and year for Lot 1 (100 percent No. 1's). These data show that on the average for the three years, the Stokesdale variety was inferior to the Rutgers variety with respect to both drained weight and color scores. For the factor of drained weight, (Chart IX), the Rutgers variety had a higher average score with less variation for the 1949 and 1950 season. In 1951, there was little difference in average drained weight scores, although the coefficient of variability was 2 percent higher for the Rutgers variety.

According to the data in Chart X, for the average color score obtained (Stokesdale, Grade B and Rutgers Grade A for both factors of quality) and for variation as measured by the coefficients of variability among the years, the Rutgers variety was superior to the Stokesdale variety in 1949 and 1951. In 1950, the average color score was higher with less variation for the Stokesdale variety than for the Rutgers variety.

These varietal differences are difficult to explain when considering the fact that the raw products inspector had no knowledge of the variety of tomato being graded. These data would indicate that knowledge of the varieties of tomatoes being processed is important to the canner, since other varieties may also give comparable differences.

It should be pointed out at this time that the detailed data for the various lots processed are given in Appendix I, Tables A, B, and C. These data substantiate the above statements or differences between these two varieties, that is, as the raw product quality decreases, the differences still exist between the two varieties in terms of the grade of the finished product.

E. Effect of Process

The effect of various processing techniques investigated in this study that may affect the quality of canned tomatoes will be discussed under (1) the effect of coring methods (hand coring versus Hydrout) and (2) the effect of type of salt added (sodium chloride versus sodium chloride-calcium chloride tablets).

1. Effect of Hand-Coring and Hydrout Coring Methods.

The tomatoes used for the major portion of this study were cored by hand using the Mark Lowe Coring Spoon. In order to determine the effect of coring tomatoes with a mechanical machine (Hydrout) and its effect upon the grade, a series of experiments

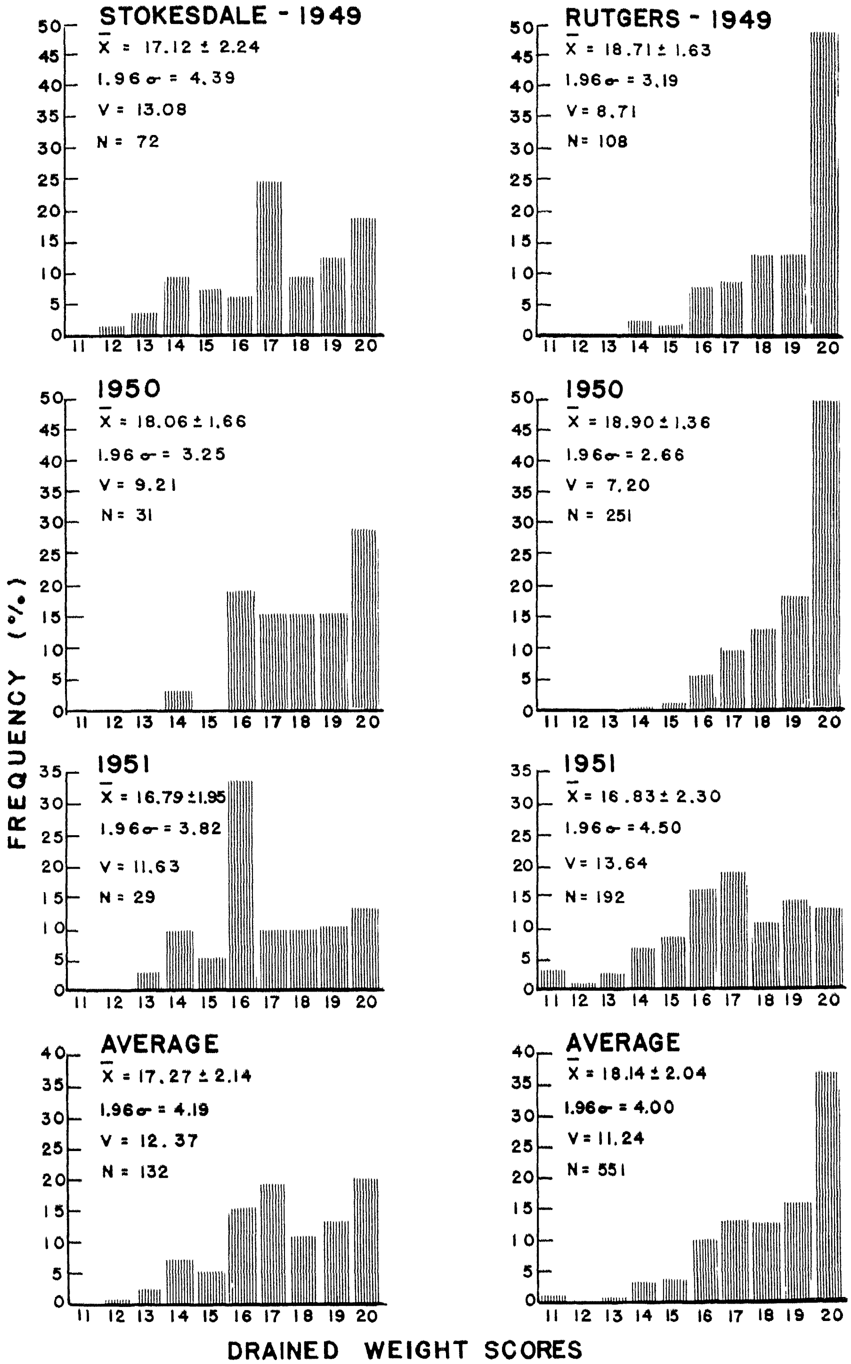


Chart IX.—Frequency distribution of drained weight scores of canned tomatoes by variety and year (Lot 1—100% No. 1's).

were designed in 1952. Table 6 presents the average values for each of the factors of grade and the statistical interpretation of these data. In Table 6 and Chart XI it will be noted that the

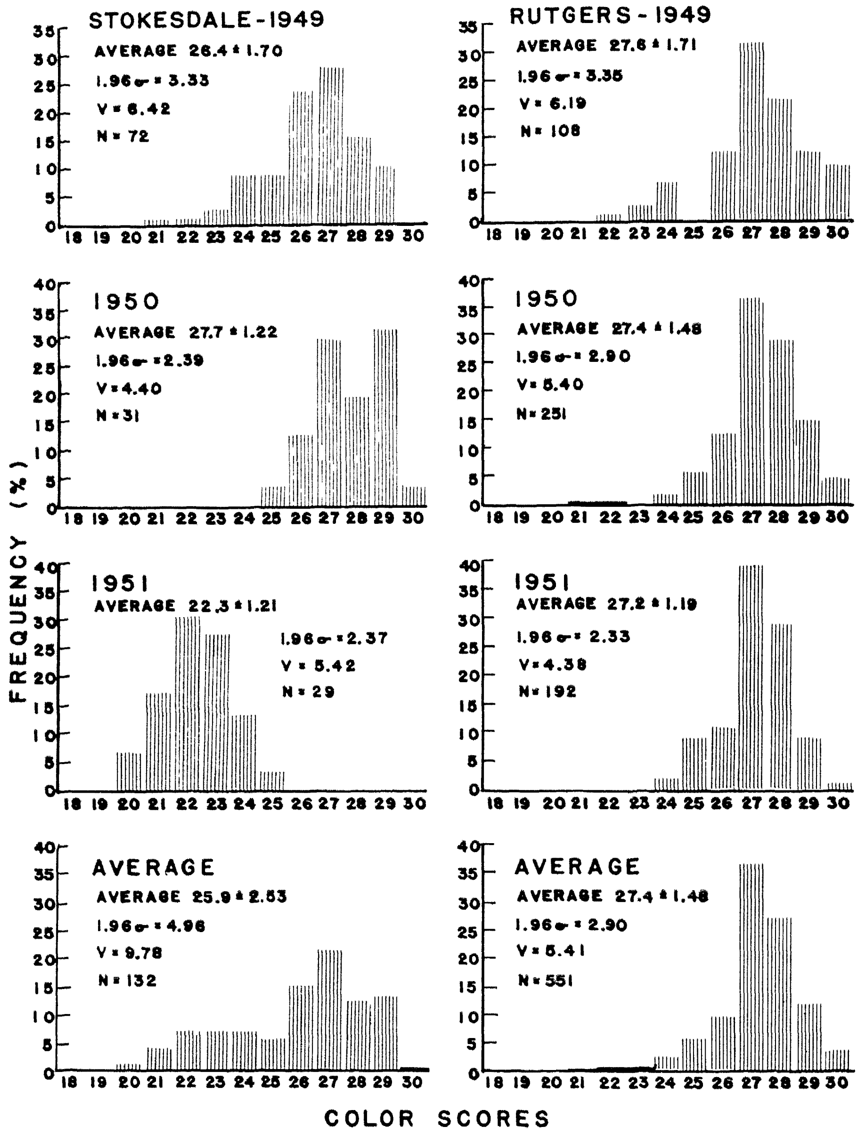


Chart X.—Frequency distribution of color scores of canned tomatoes by variety and year (Lot 1—100% No. 1's).

TABLE 6.—Effect of Method of Coring Tomatoes on Quality of Canned Tomatoes (All Lots U. S. No. 1 Tomatoes—288 Cans Evaluated for Each Standard Used)

Processed grade factors	Coring method	Average values	Standard deviation	Mean square of error	95 % ± values	Coefficient of variability
		X	σ	σ_x	1.96 σ	V
Drained weight	Hand	17.61	2.09	.123	4.10	11.87
	Hydrout	18.03	1.73	.102	3.39	9.60
Wholeness	Hand	17.69	0.69	.041	1.35	3.90
	Hydrout	17.63	0.66	.039	1.30	3.90
Color	Hand	28.17	1.22	.072	2.39	4.33
	Hydrout	28.05	1.28	.075	2.51	4.56
Defects	Hand	29.50	0.966	.057	1.89	3.27
	Hydrout	29.36	0.929	.055	1.82	3.16
Total score	Hand	92.96	2.82	.166	5.53	3.03
	Hydrout	93.08	2.56	.151	5.02	2.75

drained weight factor is the only quality factor in which differences were observed between hand and mechanical coring. The differences here were in favor of the mechanical method of coring tomatoes. These interpretations of the data are not intended to imply that all raw product qualities of tomatoes will react in the same manner. As pointed out above only tomatoes of U. S. No. 1 quality were used in these coring studies. However, had the tomatoes been cored with the Smiley Coring Knife, the results might have been more in favor of the mechanical corer. This inference was drawn from the work of Haverkamp and Hardin (13) who showed that canned tomatoes were graded one grade higher when using the Mark Lowe Coring Spoon as opposed to the Smiley Coring Knife.

2. Effect of Type of Salt Used in Packing Tomatoes.

In Table 7 and Chart XII data are presented to show the effect of the use of sodium chloride salt tablets alone and sodium chloride-calcium chloride salt tablets on the various grade factors of canned tomatoes. These data were collected in the 1952 season using the Rutgers variety of tomatoes and replicating three times during the season. Further, in Table 7, statistical data are presented as a means of interpreting the above data.

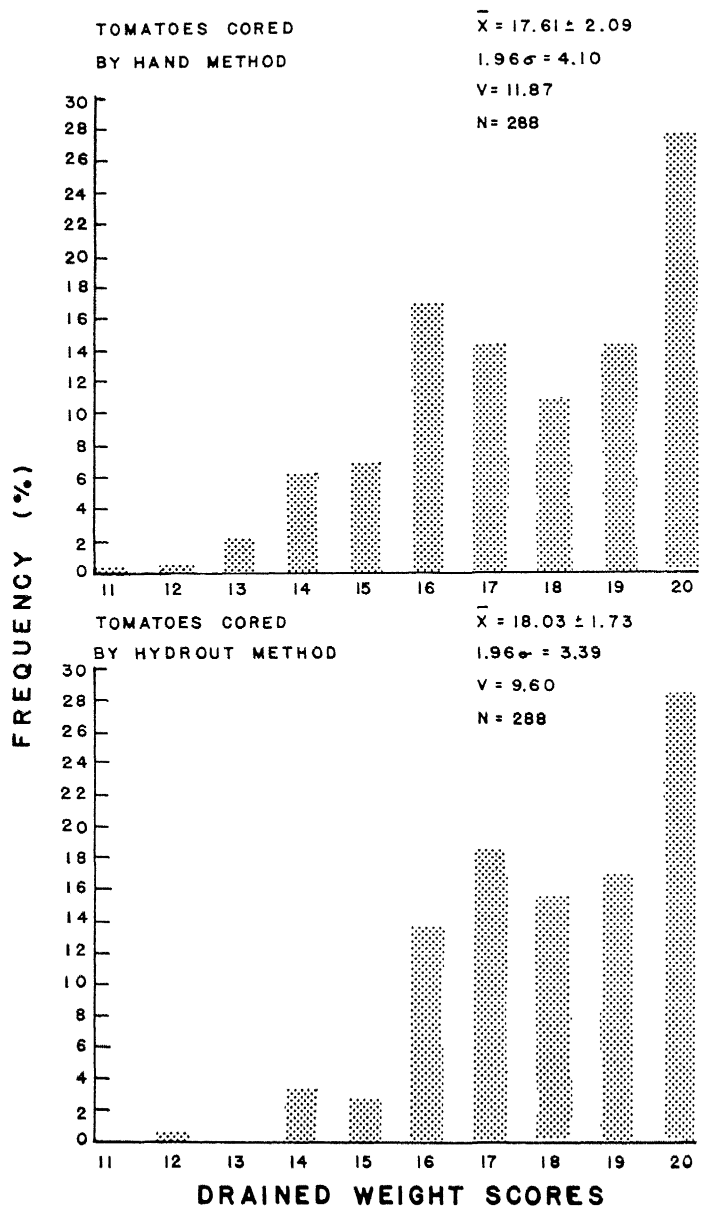


Chart XI.—Frequency distribution curves for drained weight scores for canned tomatoes cored by hand and Hydrout methods.

TABLE 7.—Effect of Type of Salt Used in Packing Tomatoes on the Grade of Canned Tomatoes (All Lots 100% U. S. No. 1's—288 Cans of Tomatoes Evaluated for Each Type of Salt Used)

Processed grade factors	Type of salt used*	Average values X	Standard deviation σ	Mean square of error σ_x	95% $\pm$ values $1.96\,\sigma$	Coefficient of variability V
Total score	NaCl	92.31	2.71	0.160	5.31	2.94
	$CaCl_2$	93.75	2.48	0.146	4.86	2.64
Drained weight	NaCl	17.31†	2.06	0.121	4.04	11.90
	$CaCl_2$	18.35	1.62	0.095	3.18	8.83
Color	NaCl	28.12	1.20	0.071	2.35	4.27
	$CaCl_2$	28.09	1.29	0.076	2.53	4.59
Wholeness	NaCl	17.45	0.608	0.036	1.19	3.48
	$CaCl_2$	17.87	0.670	0.039	1.25	3.75
Defects	NaCl	29.40	0.940	0.055	1.84	3.20
	$CaCl_2$	29.45	1.130	0.066	2.21	3.84

*NaCl —30 grains sodium chloride salt tablet.

$CaCl_2$—18.2 grains of sodium chloride and 11.8 grains of calcium chloride combined in one tablet.

†Indicates limiting rule within grade—this lot is Grade B on account of drained weight scoring in the Grade B range.

The use of the data presented in Table 7 should help the tomato processor to better control the quality of canned tomatoes. These data clearly show that the drained weights of canned tomatoes were materially affected by the addition or use of calcium chloride in the salt tablets. The calcium chloride salt tablets tended to prevent the tomato from breaking down on canning, thus giving a better drained weight score in the finished product. The over-all difference between the two lots, as shown in Table 7, was that the lots of tomatoes packed with the sodium chloride salt tablets were Grade B due to low drained weights, while the lots with the calcium chloride-sodium chloride salt tablets were Grade A.

The statistical data in Table 7 indicate that the drained weight factor was the only factor of quality showing a statistical difference between the two types of salt used in packing tomatoes.

Contrary to the results of Ketresz, et al. (17), there was no significant improvement in the wholeness scores due to the addition of calcium chloride salt tablets to canned tomatoes when graded according to the official USDA Standards.

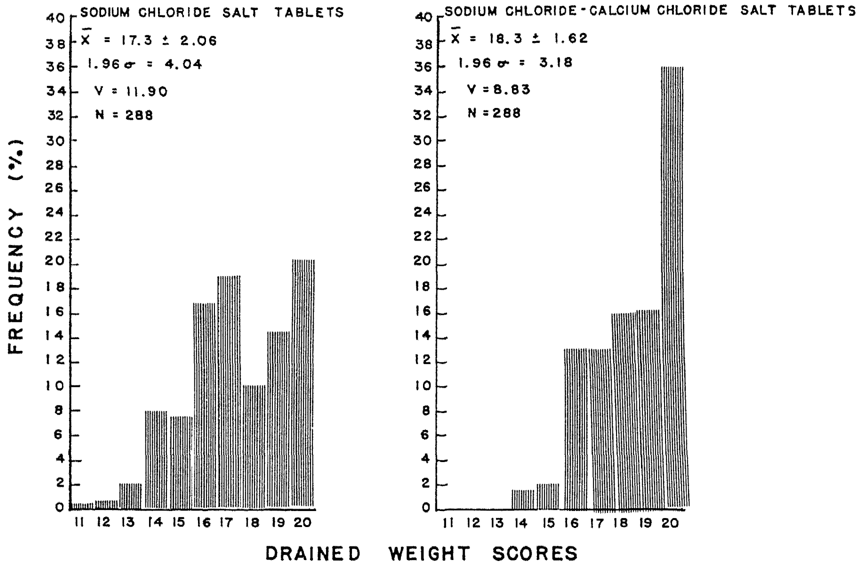


Chart XII.—Frequency distribution curves for drained weight scores for canned tomatoes packed with different types of salts.

The most significant difference was found between the coefficients of variability, which showed that tomatoes packed with calcium salt tablets had a value of 8.83 as compared to 11.90 for tomatoes packed with plain sodium chloride tablets. The frequency distribution curve shown in Chart XII illustrates the reason for this higher coefficient of variability; that is, when using calcium salts, approximately 36 percent of the samples scored the maximum value (20 points) for drained weight. When contrasted to the plain sodium chloride tablets, only approximately 20 percent of the samples scored the maximum value for drained weight.

F. Yield Studies

1. Effect of Raw Product Grade.

The relationship of yield of canned tomatoes from different grades of raw tomatoes is presented in Table 8 and Chart XIII. Before discussing these data, it should be pointed out that these data were accumulated on small lots and under pilot plant conditions. Small losses under these conditions were not accounted for in this grade relationship study. Although all cans of tomatoes were graded to determine the grade relationship, if a can was only

TABLE 8.—Yield Relationship of Canned Tomatoes by Raw Product Grade Disregarding Year and Variety

Lot No.	Raw product composition*	Number of replicates	Number of cans† packed/50 lbs.	Calculated cases packed per ton‡
1	100– 0– 0	20	39.1	48.98
2	90–10– 0	13	38.4	48.10
3	75–25– 0	17	37.4	46.85
4	75–15–10	14	37.2	46.60
5	60–35– 5	11	36.3	45.47
6	60–25–15	7	26.0	45.09
7	45–35–20	10	37.2	46.60
8	35–65– 0	7	38.5	48.22
9	100 High 1's	7	39.9	49.98
10	100 Low 1's	4	40.0	50.10
11	100 High 2's (color)	3	39.7	49.73
Average all lots			37.96	47.54

*1st number indicates percent No. 1's; 2nd number percent No. 2's account color; 3rd number percent No. 2's account defects.

†Exclusive of juice required to fill cans in which picked and trimmed tomatoes are packed.

‡Includes tomatoes for juice required to pack tomatoes.

half-filled due to insufficient raw tomatoes at the completion of packing the lot, this can of tomatoes was not processed and, consequently, it was not graded. Further, no record was kept of the juice required to fill the cans during the processing of the different lots of tomatoes. The drained weight, however, has been ascertained for the different lots of canned tomatoes, and the average drained weight of tomatoes for all cans was 13½ ounces. The average number of cans packed from all the different lots was 38.11 cans. If one takes this average number of cans (38.11 cans), and the average number of pounds of juice required to pack each 50 pound lot of tomatoes (16.53 pounds), and calculates the average number of cans packed from a given ton of tomatoes (1146 cans equivalent to 47.7 cases (24 No. 2's) per ton), we find that these results are somewhat higher than those obtained from good commercial practices. This is as would be expected for the following reasons: (1) All cull fruits were eliminated before entering the plant. (2) Generally speaking, relatively high grades of raw stock were used, and (3) Good quality control practices were exercised in the peeling, coring and trimming of the tomatoes. Regardless of the high yields obtained, the relationship of raw product

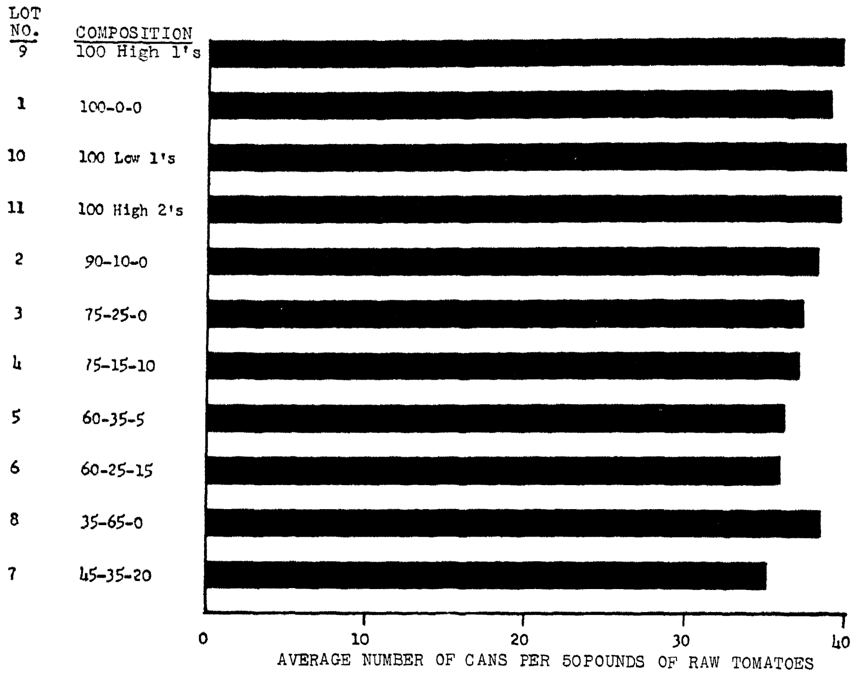


Chart XIII.—Yield relationship of canned tomatoes by raw product grade disregarding year and variety.

grade to yields as presented in Table 8 and Chart XIII shows that a difference of five cans, on the average, out of forty is found between the extreme quality levels of the raw product. Also, the lots of raw tomatoes with percentages of No. 2's for defects appear to have greater significance in the yield studies than do these lots made up of compositions of No. 1's and No. 2's for color. There is without question a better yield relationship when using high quality raw tomatoes than when using low quality raw tomatoes.

2. Effect of Season.

Table 9 presents the yield relationships for the 1949, 1950 and 1951 seasons. These data show that the average yield for 1949 was 37.48 cans, 1950 was 37.99 cans, and 1951 was 39.05 cans per 50 pounds of raw tomatoes or 46.95, 47.58 and 48.91 cases per ton, respectively, for the three years, 1949, 1950 and 1951. No direct comparison can be made of these average figures,

TABLE 9.—Yield Relationship of Canned Tomatoes by Raw Product Grade Disregarding Year and Variety

Lot No.	Raw product composition*	Year	Number of replicates	Number of cans† packed/50 lbs.	Calculated cases packed per ton‡
1	100– 0– 0	49	7	40.8	51.10
		50	7	38.6	48.35
		51	6	37.5	46.97
2	90–10– 0	49	6	38.5	48.22
		50	7	38.3	47.97
3	75–25– 0	49	5	36.8	46.09
		50	8	38.4	48.10
		51	4	36.0	45.09
4	75–15–10	49	5	37 5	46 97
		50	8	36.9	46.22
5	60–35– 5	49	5	33.7	42.21
		50	6	38.4	48.10
6	60–25–15	49	3	35.0	43.84
		50	4	36.8	46.09
7	45–35–20	49	3	36.2	45.34
		50	6	37.5	46.97
		51	1	38.0	47.60
8	35–65– 0	50	5	37.6	47.10
		51	2	40 5	50.73
9	100 High 1's	51	7	39.9	49.98
10	100 Low 1's	51	4	40.0	50.10
11	100 High 2's (color)	50	2	39.0	48.85
		51	1	41.0	51.35
12	100 Low 2's (color)	50	1	42.0	52.61
13	75– 0–25	51	1	39.0	48.85
14	35– 0–65	51	1	46.0	57.62
15	100 2's	51	1	40.0	50.10
30	34–46–20	49	1	41.5	51.98
Average of all lots		49		37.48	46.95
		50		37.99	47.58
		51		39.05	48.91

*1st number indicates percent No. 1's; 2nd number percent No. 2's account color; 3rd number percent No. 2's account defects.

†Exclusive of juice required to fill cans in which picked and trimmed tomatoes are packed.

‡Includes tomatoes for juice required to pack tomatoes.

because not all lots were packed each year. However, by referring to Table 10, one can compare three different lots of raw tomatoes that were packed each of the three years.

These data show little seasonal trend with respect to the yields obtained. It should be pointed out, however, that the tomatoes processed in these studies were sorted prior to canning into specific raw product qualities and generally did not include tomatoes of low quality due to defective areas on the fruits, except for Lot 7, which would require considerable trimming.

3. Effect of Variety.

Table 11 presents the yield relationships for the two varieties (Stokesdale and Rutgers) by raw product composition. The average yields for all lots were found to be 38.43 cans for Stokesdale variety from 34 replicates and 37.94 for Rutgers variety from 55 replicates. For certain equivalent lots of raw stock the Stokesdale variety gave a slightly higher yield than the Rutgers variety.

TABLE 10.—Yield Relationship of Canned Tomatoes by Raw Product Grade Disregarding Year and Variety

Lot No.	Raw product composition	Year	Number of replicates	Number of cans packed/50 lbs.	Calculated cases packed per ton
1	100–00– 0	49	7	40.8	51.10
		50	7	38.6	48.35
		51	6	37.5	46.97
		Average		39.04	48.90
3	75–25– 0	49	5	36.8	46.09
		50	8	38 4	48.10
		51	4	36.0	45.09
		Average		37.36	46.80
7	45–35–20	49	3	26.2	45.34
		50	6	37.5	46.97
		51	1	38.0	47.60
		Average		37.16	46.54
	Average	49		38.55	48.29
		50		38.21	47.86
		51		37.00	46.34
	Grand Average			38.04	47.64

In summarizing the yield relationship phase of this study several factors should be reemphasized: (1) all of these data have been collected under pilot plant conditions, (2) no cull tomatoes or lots of raw tomatoes with excessive percentages of No. 2 tomatoes for defects

TABLE 11.—Yield Relationship by Raw Product Composition and by Variety, Disregarding Years

Lot No.	Raw product composition*	Variety†	Number of replicates	Number of cans‡ packed/50 lbs.	Calculated cases packed per ton§
1	100– 0– 0	S	5	40.6	50.85
		R	15	38.5	48.22
2	90–10– 0	S	3	40.3	50.48
		R	10	37.8	47 35
3	75–25– 0	S	5	35.6	44.59
		R	12	38.1	47.72
4	75–15–10	S	5	38.2	47.85
		R	9	36.6	45.84
5	60–35– 5	S	4	39.4	49.35
		R	7	34.4	43.09
6	60–25–15	S	4	38 0	47.60
		R	3	33.3	41.71
7	45–35–20	S	4	37.9	47.47
		R	6	36.7	45.97
8	35–65– 0	S	2	38.0	47.60
		R	5	38 6	48.35
9	100 High 1's	R	7	39.9	49.98
10	100 Low 1's	R	4	40.0	50.10
11	100 High 2's (color)	S	1	38.0	47.60
		R	2	40.5	50.73
12	100 Low 2's (color)	R	1	42.0	52.61
13	75– 0–25	R	1	39.0	48.85
14	35– 0–65	R	1	46.0	57.62
15	100 2's	R	1	40.0	50.10
30	34–46–20 (Field Run)	R	1	41.5	51.98
Average of all lots		S		38.43	48.14
		R		37.94	47.52

*1st number indicates percent No. 1's; 2nd number percent No. 2's account color; 3rd number percent No. 2's account defects.

†S (Stokesdale); R (Rutgers).

‡Exclusive of juice required to fill cans in which picked and trimmed tomatoes are packed.

§Includes tomatoes for juice required to pack tomatoes.

(except for one replicate of Lot 14, 35-0-65) were used in this study and (3) relatively high grades of raw stock were used throughout this study.

Because of the above factors the yield relationships are somewhat better than those obtained commercially. There was a better yield relationship when using high quality raw tomatoes. Furthermore, increasing percentages of No. 2 tomatoes on account of defects gave a lower yield of finished product. There was little difference found among the years in yield relationships. Finally, the Stokesdale variety gave a slightly higher yield than did the Rutgers variety.

GENERAL DISCUSSION

The quality of the raw product determines to a major extent the quality of canned tomatoes which may be processed from the raw product. A tomato processor, if using 90 percent or better U. S. No. 1 quality tomatoes, should expect to obtain a finished product grade of Grade A or fancy quality. Also, a processor should expect to pack Grade C or Standard quality canned tomatoes from Low U. S. No. 2 Grade tomatoes. There are at least three factors, however, that affect this grade relationship. These are: (1) seasonal variations; (2) varietal variations; and (3) processing methods. Therefore, in order to predict the grade relationship with reasonable accuracy, the tomato processor must have knowledge or control of these three variables. Before discussing these three variables in the grade relationship, the data obtained in this study have shown the quality differences in canned tomatoes to be mainly reflected in two of the factors of grade, that is, drained weight and color. These two factors for grade represented fifty percent of the total score for canned tomatoes when scored in accordance with the USDA grading system.

These two factors of the finished product grade were found to vary with the quality of the raw product with the above three factors affecting the grade relationship. The drained weight score for canned tomatoes as determined in this study appears to be a good objective method (Figure 4) of determining in part the quality of the finished product. Drained weight is affected by the above cited variables and consequently the processor can control drained weight to a great extent by controlling: (1) variety—Rutgers was superior to Stokesdale; (2) grade—lower grades of raw product were found to give higher drained weight scores and (3) to offset the low drained weight scores obtained with higher grades of raw product, it was shown that the addition of calcium salts increased the drained weight scores.

The scores for color in canned tomatoes were found to be affected by grade, variety and season. Better colored tomatoes in the raw product gave higher color scores in the canned product. This is as would be expected since the raw product grade is based primarily on color. Results of this study have shown the direct relationship between raw product color and finished product color. The color of the raw tomatoes and the canned tomatoes should be evaluated under uniform standardization lighting conditions (Figure 5) (11) due to the importance of the color of the raw product to the color score of the finished product. Furthermore, the U. S. No. 2 tomatoes in the raw product should be sorted into those that are U. S. No. 2's for color and those that are U. S. No. 2's for defects. This would provide the tomato grower with additional needed information when harvesting tomatoes. Also, the processor should have this knowledge of the percentages of 2's for color in the raw product when attempting to pack any particular grade of canned tomatoes.

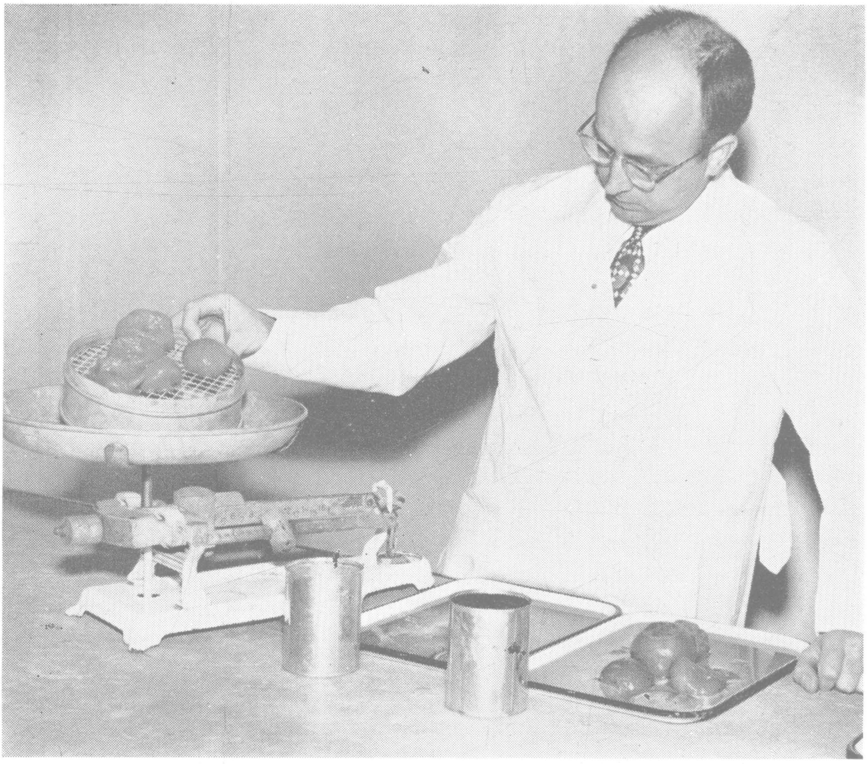


Fig. 4.—Determining the drained weight of canned tomatoes.

The other two factors, wholeness and absence of defects, were found to have little effect on the processed grade. The wholeness factor, representing twenty percent of the total grade, did not vary appreciably among the seasons, between varieties, or with the various qualities of raw product used in this study. Practically all of the lots scored in the Grade B range for wholeness. Further analysis showed that approximately 75 percent of all the canned tomatoes graded were scored in the Grade B classification (Chart XIV). A breakdown of the samples with scores falling in the Grade B range showed that approximately 72 percent of all Grade B samples were scored 17 points for wholeness. The factor of wholeness does not carry the limiting rule, and, therefore, did not affect the overall grade except for lowering the total score. Therefore, it would be concluded that the wholeness factor as now determined is not as important as the possible 20 points out of 100 points might indicate.

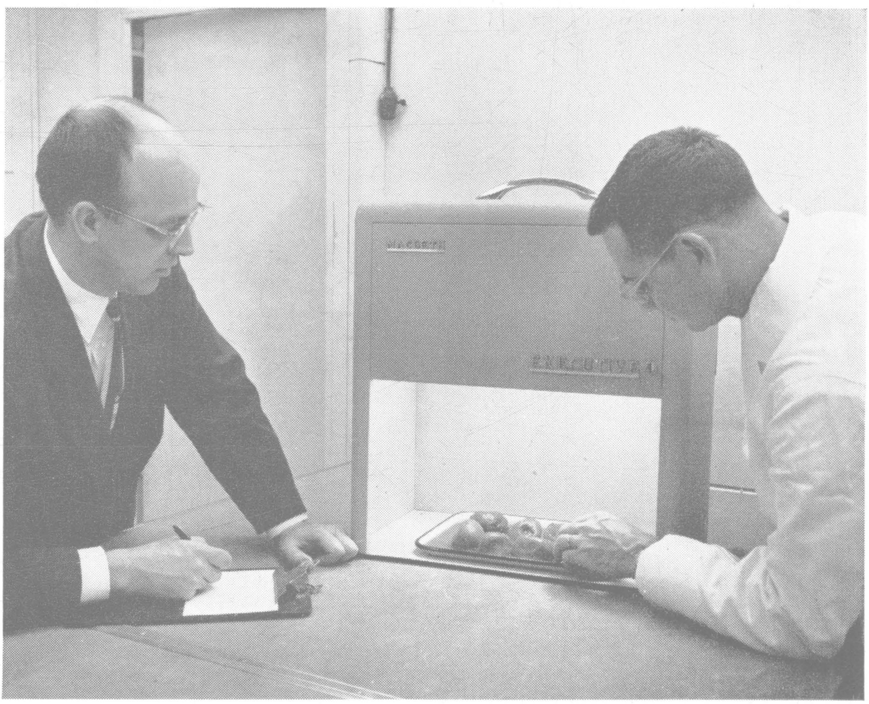


Fig. 5.—Evaluating color of canned tomatoes using the Macbeth Executive standardized light.

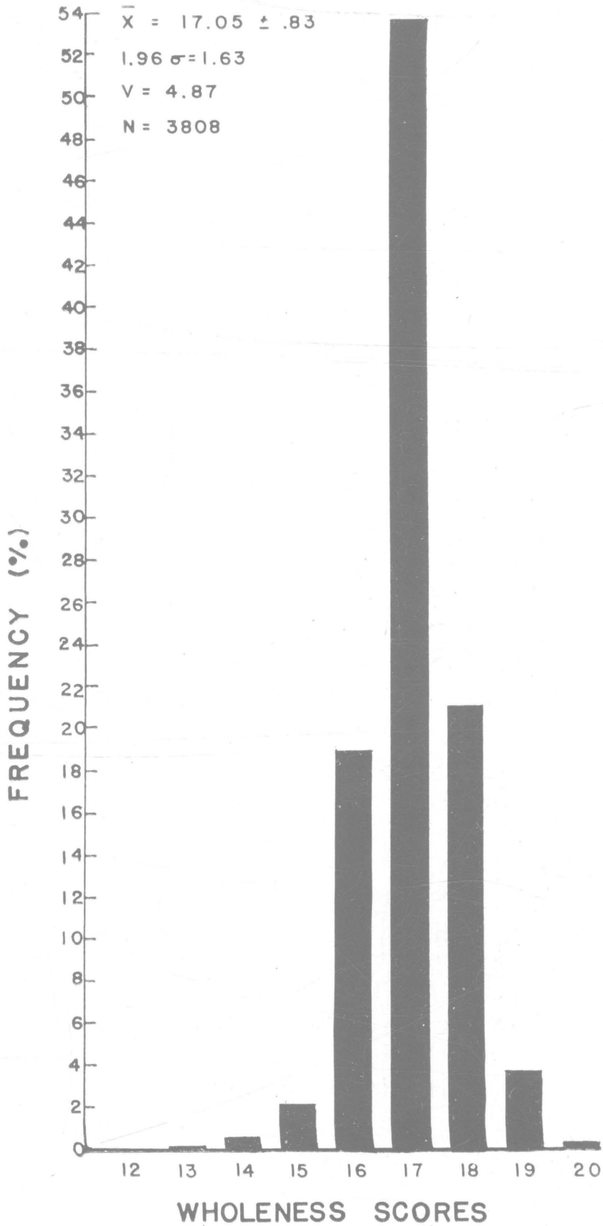


Chart XIV.—Frequency distribution curve for wholeness score for canned tomatoes for years (1949, 1950, 1951).

The fourth factor of grade, absence of defects, represents thirty points out of a hundred points, and in all cases except one (a field run lot), the lots scored in the Grade A range for the factor of absence of defects. This may not be the case under normal commercial conditions. The reasons for the high scores for absence of defects as found in this study was probably due to (1) relatively high grade of raw product (all cull tomatoes were removed before processing); (2) this study was concerned with quality relationships and the production of large quantities was not involved; (3) a better coring device was used than is generally found in commercial use; and (4) good quality control practices were exercised throughout the trimming, peeling, and processing of these tomatoes.

From a seasonal standpoint, these data show variations when using tomatoes of the same variety and quality of raw product, and the same processing techniques. There is little that the processor can do to control seasonal variations except to use varieties which are best suited for his area of production; to encourage growers to use the best known cultural practices, and to practice good processing and control techniques from harvest to the canning plant.

From a variety standpoint and on the basis of the three years results of this study (1949, 1950 and 1951), the Rutgers variety was found to be superior to the Stokesdale variety of tomatoes for canning purposes except for the Stokesdale variety being slightly superior to the Rutgers from a yield standpoint. In general, the Rutgers variety produced canned tomatoes of higher scores for drained weights and color. Over the three year period, the Rutgers variety averaged Grade A canned tomatoes for color and drained weight when produced from 100 percent U. S. No. 1 lots. The Stokesdale variety, however, averaged Grade B canned tomatoes for color and drained weight when produced from 100 percent U. S. No. 1 lots. Thus, the processor should use the variety best suited for his area and the processor should have adequate varietal test data available as to the effect of processing on the grade relationship before making sizable plantings of new varieties.

The processing variables that were investigated in this study were (1) coring tomatoes by hand and by machine and (2) packing tomatoes with plain sodium chloride salt and sodium chloride-calcium chloride salt tablets.

Comparable tests of tomatoes cored by hand or machine gave similar grades in the finished product. By using the machine to core tomatoes, it was possible to increase production in the pilot plant or to reduce the labor involved in coring approximately 25 percent. Therefore, it would appear from these data that the tomato processor should consider machine coring of tomatoes for canning from these three viewpoints: (1) quality, (2) labor and (3) production. It should be pointed out at this time that all machine-cored tomatoes in this study were cored after washing but prior to steam scalding. This practice was found to be the best for utilizing this tomato coring machine.

As for the use of calcium salts in improving the quality (drained weight) of canned tomatoes, calcium salts are permitted by Federal regulation as long as their use is declared on the label. Data from this study indicate that comparable lots of tomatoes packed with added calcium chloride salt tablets were improved one grade over comparable lots of tomatoes packed with sodium chloride tablets. Therefore, the tomato processor can obtain a higher grade of canned tomatoes by the addition of calcium salts.

Contrary to statements in the literature, the data obtained in this study showed that calcium salts did not appreciably increase the wholeness scores of canned tomatoes. This can be partly explained, as previously pointed out, on the basis that wholeness scores were determined subjectively and that the tomatoes as used in this study probably did not represent as great a range in quality as might be found commercially.

SUMMARY

Tomatoes are the leading vegetable crop processed in Ohio. A large percentage of the raw crop is purchased from the farmer on a grade basis. The grade is determined by Federal-State Inspectors using the U. S. Standards for Canning Tomatoes or U. S. Standards for Tomatoes for Manufacture of Strained Tomato Product. However, little information is available on the grade relationship between the raw and the processed products.

Known grades of raw tomatoes (Rutgers and Stokesdale varieties) were processed under pilot plant conditions using acceptable commercial practices and the grade of the finished product was determined by a Processed Products Inspector in accordance with the U. S. Standards to study this grade relationship. The study was conducted during the years 1949 to 1952 inclusive. The following statements summarize the major results:

1. The relationship of raw product grade to processed product grade shows that a processor can expect to pack Grade A or Fancy tomatoes from 90 percent or better U. S. No. 1 tomatoes.

2. The relationship of raw product grade to processed product grade shows that a processor can expect to pack Grade C or Standard tomatoes from Low U. S. No. 2 tomatoes.

3. The reasons for the inability to obtain a higher grade of finished product from the lower grades of raw stock are (1) color and (2) drained weight. Under the pilot plant conditions used in this study, wholeness and defects were not important factors of grade. This was due to good quality control practices used in the pilot plant in the peeling and coring of tomatoes.

4. For any equivalent raw product quality the Stokesdale variety was found to be inferior to the Rutgers variety. This was due to poorer color retention and lower drained weight scores.

5. When the raw product was graded on the basis of the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products, there were no significant differences found in the grades of the canned tomatoes packed from comparable qualities of U. S. No. 1 Grade raw tomatoes.

6. Tomatoes cored by machine (Hydrout) were graded approximately the same as those cored by hand. However, machine coring increased production or reduced labor approximately 25 percent.

7. The use of calcium salts, in the packing of tomatoes gave higher drained weight scores in the canned product.

CONCLUSIONS

On the basis of this study, it is concluded that there is a direct relationship between the raw product grade and the grade of canned tomatoes. Furthermore, by knowing the raw product grade and by using good quality control practices within the plant it is possible to predict the grade of the finished product. It is believed that if canners would utilize the raw product grade in selecting the loads of raw tomatoes for each quality contemplated, a more uniform pack of known quality of canned tomatoes would be obtained.

RECOMMENDATIONS

1. The present U. S. Standards for Canning Tomatoes and the U. S. Standards for Tomatoes for Manufacture of Strained Tomato Products could be better utilized by the classification of the No. 2 tomatoes into those that are No. 2's for color and those that are No. 2's for defects.
2. The present U. S. Standards for Grades of Canned Tomatoes be revised to place less weight on the "wholeness" factor.

SELECTED BIBLIOGRAPHY

1. Anonymous. U. S. Standards for Grades of Canning Tomatoes. U. S. Dept. of Agriculture. Effective August 1, 1946.
2. Anonymous. Standard of Identity for Canned Tomatoes. Food & Drug Administration. Effective January 1, 1940.
3. Appleman, C. O. and Conrad, C. M. The Pectic Constituents of Tomatoes and Their Relation to the Canned Product. Maryland Agr. Expt. Sta. Bul. 291, 1927.
4. Fawcett, K. I., Gaylord, F. C. and Desrosier, N. W. Quality of Raw vs. Finished Product in Canned Tomatoes. Purdue Univ. Agr. Expt. Sta. Bul. 605. February 1954.
5. Gaylord, F. C. and MacGillivray, J. H. Buying Tomatoes on Grade. Purdue Agr. Expt. Sta. Bul. 336, 1930.
6. Gaylord, F. C. and Fawcett, K. I. A Survey of Methods of Delivering Cannery Tomatoes. The Canner. June 26, 1943.
7. Gaylord, F. C. and Fawcett, K. I. Tomatoes by Appointment. The Canner. January 29, 1944.
8. Gaylord, F. C. and Fawcett, K. I. A Study of Grade, Quality, and Price of Canned Tomatoes Sold at Retail in Indiana. Purdue Univ. Agr. Expt. Sta. Bul. 495, 1944.
9. Gould, W. A., Davis, Rees B., Krantz, F. A., Jr., and Healy, N. C. A Study of the Relationship of Various Grades of Fresh and Canned Vegetables. I. Canned Tomatoes. Ohio Agr. Expt. Sta., Dept. of Horticulture Mimeo. Series No. 53 - 1. April 1953.
10. Gould, W. A. Hydrout Corer Helps Quality and Saves Labor in Canning Tomatoes, OSU Tests Show. Food Packer 34 (9) 30-32, 1953.
11. Gould, W. A., Davis, Rees B., Mavis, James O. Color Grading Agricultural Products. ASTM Bul. No.'s. 201 and 202, p. 19-25, October and December 1954.
12. Hauck, Chas. W. Marketing Cannery Tomatoes on Grade in Ohio. Ohio Agr. Expt. Sta. Bul. 504. August 1932.
13. Haverkamp, L. J. and Hardin, L. S. Simplifying Tomato Canning Operations. Purdue Univ. Agr. Expt. Sta. Bul. 528. April 1948.
14. Jacobs, M. B. **Food and Food Products.** Interscience Pub. Co. Vol. III, p. 1979; 2nd Ed., 1951.
15. Kertesz, Z. I. How Pectic Enzymes Influence the Quality of Tomato Products. The Canner, 88: No. 1, 11. 1938.
16. Kertesz, Z. I. Pectic Enzymes II. Pectic Enzymes of Tomatoes. Food Research 3: (5) 481-487, 1938.
17. Kertesz, Z. I., Tolman, T. G., Loconti, J. D. and Ruyle, E. H. The Use of Calcium in the Commercial Canning of Whole Tomatoes. New York State Agr. Expt. Sta. Bul. 252. April 1940.
18. Kertesz, Z. I. and Loconti, J. D. Factors Determining the Consistency of Commercial Canned Tomato Juice. New York State Agr. Expt. Sta. Bul. 272. March 1944.
19. Loconti, J. D. and Kertesz, Z. I. Identification of Calcium Pectate as the Tissue-firming Compound Formed by Treatment of Tomatoes with Calcium Chloride. Food Research 6: No. 5, p. 499, 1941.
20. LeCrone, F. and Haber, E. S. Changes in the Pectin Constituents of Tomatoes in Storage. Iowa State College Jour. Sci. 7: 467-476. 1933.
21. Siegel, M. A New Calcium Compound for Firming Tomatoes for Canning. The Canner. February 13, 1943.
22. Smith, M. G., et al. An Economic Analysis of the Production of Canning Factory Tomatoes in Indiana. Purdue Agr. Expt. Sta. Bul. 456. 1940.

Appendix Table A—Grade Relationship of Canned Tomatoes By Raw Product Composition, Variety (Stokesdale & Rutgers), and Year (1949, 1950, 1951), and Process (Packed for Grade 4, and Mine Run 3)
Stokesdale (S) Rutgers (R)

Lot No.	Composition	Varieties	Year	Process	Can Count	Total Score	Drained Weight	Color	Wholeness	Defects	Lot Grade
1	100–00– 0	S	49	3	72	89.8*	17.0	26.5*	17.0	29.3	B
			50	3	31	92.4	18.1	27.8	17.4	29.1	A
			51	3	29	82.7*	16.8*	22.3*	15.5	28.1	C
		Average		3	132	88.8*	17.2*	25.9*	16.7	29.0	B
1	100–00– 0	R	49	3	72	93.1	19.0	27.2	17.6	29.2	A
			49	4	36	93.0	18.2	28.4	17.1	29.5	A
			49	3 & 4	108	93.1	18.7	27.6	17.4	29.3	A
			50	3	213	92.4	18.8	27.4	17.4	28.8	A
			50	4	38	93.0	19.3	27.3	17.5	29.0	A
			50	3 & 4	251	92.5	18.9	27.4	17.4	28.8	A
			51	3	192	89.7*	16.8*	27.2	17.1	28.6	B
		Average		3	477	91.4	18.0	27.3	17.3	28.8	A
		Average		4	74	93.0	18.8	27.8	17.3	29.1	A
		Average		3 & 4	551	91.6	18.1	27.4	17.3	28.9	A
	Average by year		49		180	91.8	18.1	27.2	17.2	29.3	A
			50		282	92 5	18.8	27.4	17.4	28.9	A
			51		221	88 7*	16.8*	26.5*	16.9	28.5	B
	Grand average				683	91.1	18.0	27.0	17.2	28.9	A
2	90–10– 0	S	49	3	48	89.7*	18.3	25.5*	16.9	29.0	B
			50	3	37	89.0*	17.7	25.8*	16.5	29.0	B
		Average		3	85	89.4*	18.1	25.6*	16.7	29.0	B
2	90–10– 0	R	49	3	66	93.9	19.5	27.6	17.7	29.2	A
			50	3	179	92.6	18.9	27.4	17.2	29.0	A
			50	4	36	93.0	19.7	27.1	17.3	29.0	A
			50	3 & 4	215	92.6	19.0	27.4	17.2	29.0	A
		Average		3	245	92.9	19.1	27.5	17.3	29.0	A
		Average		3 & 4	281	92.9	19.2	27.4	17.3	29.0	A
	Average by year		49		114	92.1	19.0	26.7	17.4	29.1	B
			50		252	92.1	18.9	27.1	17.1	29.0	A
	Grand average				366	92.1	18.9	27.0	17.2	29.0	A
3	75–25– 0	S	49	3	48	87.9*	18.2	24.1*	16.9	28.7	B
			50	3	71	87.4*	17.5*	25.2*	16.3	28.4	B
			51	3	25	82.3*	16.0*	22.2**	15.3	28.8	C
		Average		3	144	86.7*	17.5*	24.3*	16.3	28.0	B
3	75–25– 0	R	49	3	42	93.5	19.6	27.5	17.2	29.2	A
			49	4	18	91.2	18.6	27.6	16.9	28.7	A
			49	3 & 4	60	93.0	19.2	28.0	17.1	29.1	A
			50	3	174	91.2	18.9	26.1*	17.3	29.0	B
			50	4	38	92.0	19.1	26.4*	17.4	29.0	B
			50	3 & 4	212	91.4	18.9	26.2*	17.3	29.0	B
			51	3	117	88.6*	17.3*	25.7*	17.2	28.4	B
		Average		3	333	90.6	18.4	26.2*	17.2	28.8	B

Lot No.	Composition	Varieties	Year	Process	Can Count	Total Score	Drained Weight	Color	Wholeness	Defects	Lot Grade
		Average		4	56	91.9	18.9	26.8*	17.2	28.9	B
		Average		3 & 4	389	90.8	18.5	26.3*	17.2	28.8	B
			49		108	90.7	18.8	26.0*	17.0	28.9	B
	Average by year		50		283	90.4	18.6	25.9*	17.1	28.8	B
			50		142	87.5*	17.1*	25.1*	16.9	28.4	B
	Grand average				533	89.7*	18.2	25.7*	17.0	28.8	B
4	75–15–10	S	49	3	66	87.7*	17.6*	24.9*	16.7	28.4	B
			50	3	60	89.0*	18.9	25.5*	16.5	28.1	B
		Average		3	126	88.3*	18.2	25.2*	16.6	28.3	B
4	75–15–10	R	49	3	42	93.7	19.7	27.8	17.1	29.1	A
			49	4	18	90.4	18.3	27.3	16.9	27.8	A
			49	3 & 4	60	93.0	19.2	28.0	17.0	28.7	A
			50	3	176	92.8	19.0	27.4	17.4	29.0	A
			50	4	37	92.8	19.6	26.2*	17.6	29.3	B
			50	3 & 4	213	92.8	19.1	27.2	17.4	29.1	A
		Average		3	218	93.0	19.2	27.5	17.3	29.0	A
		Average		4	55	92.0	19.2	26.6*	17.4	28.8	B
		Average		3 & 4	273	92.8	19.2	27.3	17.3	29.0	A
			49		126	90.1	18.4	26.2*	16.9	28.6	B
	Average by year		50		273	92.0	19.1	26.8*	17.2	28.9	B
	Grand average				399	91.4	18.9	26.6*	17.1	28.8	B
5	60–35– 5	S	49	3	48	90.5	18.8	26.0*	16.6	29.1	B
			50	3	75	90.5	19.0	25.9*	16.9	28.7	B
		Average		3	123	90.5	18.9	25.9*	16.8	28.9	B
5	60–35– 5	R	49	3	41	92.4	19.6	27.2	16.8	28.9	A
			49	4	18	87.7	17.8	26.2*	15.9	27.8	B
			49	3 & 4	59	90.6	19.0	26.9*	16.2	28.5	B
			50	3	146	92.1	19.2	26.5*	17.3	29.1	B
		Average		3	187	92.2	19.3	26.6*	17.2	29.0	B
		Average		3 & 4	205	91.8	19.2	26.6*	17.1	28.9	B
			49		107	90.8	18.9	26.5*	16.6	28.8	B
	Average by year		50		221	91.6	19.2	26.3	17.1	29.0	B
	Grand average				328	91.3	19.0	26.4*	17.0	28.9	B
6	60–25–15	S	49	3	46	89.4*	18.1	26.1*	16.1	28.6	B
			50	3	65	89.1*	18.5	26.0*	16.7	27.9	B
		Average		3	111	89.3	18.4	26.0*	16.7	28.2	B
6	60–25–15	R	49	3	24	91.3	19.0	27.3	16.3	28.7	A
			50	3	87	92.2	19.3	26.5*	17.2	29.2	B
		Average		3	111	92.0	19.3	26.6*	17.0	29.1	B
			49		70	90.1	18.4	26.6*	16.5	28.6	B
	Average by year		50		152	90.9	19.0	26.3*	17.0	28.6	B
	Grand average				222	90.6	18.9	26.3*	16.8	28.6	B

Lot No.	Composition	Varieties	Year	Process	Can Count	Total Score	Drained Weight	Color	Wholeness	Defects	Lot Grade
7	45–35–20	S	49	3	42	86.5*	18.4	24.3*	16.2	27.5	B
			50	3	63	90.1	18.2	26.3*	16.9	28.7	B
		Average		3	105	88.7*	18.3	25.5*	16.6	28.3	B
7	45–35–20	R	49	3	25	92.0	19.8	27.0	16.8	28.4	A
			50	3	144	92.2	19.6	26.3*	17.4	28.9	B
			51	3	38	89.4*	17.3*	26.6*	17.0	28.5	B
		Average		3	207	91.7	19.2	26.4	17.3	28.8	B
			49		67	88.6*	18.9	25.4*	16.4	27.9	B
	Average by year		50		207	91.6	19.2	26.3*	17.3	28.8	B
			51		38	89.4*	17.3*	26.6*	17.0	28.5	B
	Grand average				312	90.7	18.9	26.1*	17.1	28.6	B
8	36–65– 0	S	50	3	75	87.7*	18.3	24.5	16.5	28.4	B
8	36–65– 0	R	50	3	108	89.5*	19.0	24.5*	17.2	28.8	B
			51	3	81	90.0	17.9*	26.4*	17.3	28.4	B
		Average		3	189	89.6*	18.5	25.3*	17.2	28.6	B
			50		183	88.7*	18.7	24.5*	16.9	28.6	B
	Average by year		51		81	90.0	17.9*	26.4*	17.3	28.4	B
	Grand average				264	89.1*	18.4	25.1*	17.0	28.6	B
9	100 Hi'h 1's	R	51	3	272	90.8	17.2*	27.7	17.1	28.8	B
10	100 Low 1's	R	51	3	158	90.3	17.7*	26.7*	17.2	28.7	B
11	100 Hi'h 2's	S	50	3	30	88.4*	19.3	23.9*	16.6	28.6	B
		R	50	3	38	91.5	19.1	25.9*	17.3	29.2	B
			51	3	41	88.7*	18.3	25.1*	17.4	27.9	B
		Average			79	90.1	18.7	25.5*	17.4	28.5	B
	Average by year		50	3	68	90.1	19.2	25.0*	17.0	28.9	B
			51	3	41	88.7*	18.3	25.1*	17.4	27.9	B
	Grand average				109	89.6*	18.9	25.1*	17.1	28.5	B
12	100 Low 2's	R	50	3	42	88.4*	19.2	22.9**	17.4	28.0	C
13	75– 0–25	S	50	3	40	87.6	19.0	23.9*	16.7	28.0	B
		R	51	3	39	87.1	15.4*	26.9*	16.3	28.5	B
		Average			79	87.4	17.2*	25.4*	16.5	28.3	B
14	35– 0–65	R	51	3	36	86.2*	16.5*	24.2*	17.0	28.5	B
15	100 2's	R	51	3	40	86.8*	16.8*	25.2*	16.9	27.9	B
30	34–46–20 (Field Run)	R	49	3	24	83.8*	17.0*	24.5*	16.5	25.8*	B

*Indicates limiting rule within classification.

Appendix Table B.—Statistical Analyses of Color Scores of Canned Tomatoes by Raw Product Composition, Variety (Stokesdale (S) and Rutgers (R), Year (1949, 1950 and 1951) and Process (Packed for Grade-4, and Mine Run-3)

Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values $\bar{X}$	Standard Deviation σ	Mean Square of Error $\sigma_{\bar{x}}$	95% ± Values 1.96 σ	Coefficient of Variability V
1	100—00— 0	S	49	3	72	26.45	1.68	.198	3.29	6.37
			50	3	31	27.75	1.22	.218	2.39	4.39
			51	3	29	22.30	1.21	.225	2.37	5.44
			Average	3	132	25.86	2.45	.213	4.80	9.47
1	100—00— 0	R	49	3	72	27.25	1.75	.206	3.43	6.42
			49	4	36	28.36	1.36	.227	2.66	4.80
			49	3 & 4	108	27.62	1.71	.164	3.35	6.19
			50	3	213	27.41	1 36	.093	2.66	4.96
			50	4	38	27.26	2.02	.328	3.96	7.41
			50	3 & 4	251	27.39	1.48	.093	2.90	5.40
			51	3	192	27.16	1.18	.058	2.31	4.34
			Average	3	477	27.28	1.36	.062	2.66	4.98
			Average	4	74	27.80	1.81	.210	3.55	6.51
			Average	3 & 4	551	27.35	1.48	.063	2.90	5.41
	Average by year		49		180	27.16	1.80	.134	3.53	6.63
			50		282	27.42	1.46	.087	2.86	5.32
			51		221	26.52	2.01	.135	3.98	7.58
	Grand Average				683	27.06	1.79	.068	3.51	6.61
2	90—10— 0	S	49	3	48	25.48	1.48	.214	2.90	5.82
			50	3	37	25.81	2.01	.331	3.94	7.79
			Average	3	85	25.62	1.74	.189	3.41	6.80
		R	49	3	66	27.56	1.63	.201	3.19	5.91
			50	3	179	27.46	1.57	.117	3.08	5.72
			50	4	36	26.64	1.86	.310	3.64	6.98
			50	3 & 4	215	27.30	1.64	.112	3.21	6.01
			Average	3	245	27.49	1.59	.102	3.12	5.78
			Average	3 & 4	281	27.42	1.73	.103	3.39	6.31
	Average by year		49		114	26.68	1.87	.175	3.66	7.01
			50		252	27.19	1.94	.122	3.80	7.15
	Grand Average				366	27.01	1.89	.089	3.70	7.00
3	75—25— 0	S	49	3	48	24.10	2.01	.291	3.94	8.34
			50	3	71	25.18	1.84	.218	3.60	7.31
			51	3	25	22.16	1.51	.302	2.95	6.81
			Average	3	144	24.30	2.15	.179	4.21	8.85

Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values $\bar{X}$	Standard Deviation σ	Mean Square of Error σ_{ϵ}	95% ± Values 1.96 σ	Coefficient of Variability V
3	75–25– 0	R	49	3	42	27.50	1.22	.189	2.39	4.44
			49	4	18	27.56	1.70	.401	3.33	6.17
			49	3 & 4	60	27.43	1.60	.207	3.14	5.83
			50	3	174	26.14	1.86	.141	3.64	7.12
			50	4	38	26.50	3.67	.600	7.19	13.85
			50	3 & 4	212	26.16	2.34	.161	4.59	8.94
			51	3	117	25.72	1.73	.160	3.39	6.73
		Average		3	333	26.16	1.83	.100	3.59	6.70
		Average		4	56	26.84	3.21	.429	6.29	11.96
		Average		3 & 4	389	26.22	2.14	.108	4.19	8.16
			49		108	25.95	2.37	.228	4.64	9.13
	Average by year		50		283	25.92	2.21	.131	4.33	8.53
			51		142	25.09	2.17	.182	4.25	8.65
	Grand Average				533	25.70	2.30	.996	4.51	8.95
4	75–15–10	S	49	3	66	24.92	2.18	.268	4.27	8.75
			50	3	60	27.68	1.63	.211	3.19	5.89
		Average		3	126	26.24	2.38	.212	4.66	9.07
4	75–15–10	R	49	3	42	27.83	1.29	.199	2.53	4.64
			49	4	18	27.33	.18	.514	4.27	7.98
			49	3 & 4	60	25.51	1.57	.203	3.08	6.15
			50	3	176	27.41	2.59	.195	5.08	9.45
			50	4	37	26.30	3.09	.508	6.06	11.74
			50	3 & 4	213	27.21	2.00	.137	3.92	7.35
		Average		3	218	27.49	1.51	.102	2.96	5.49
		Average		4	55	26.64	2.87	.387	5.62	10.77
		Average		3 & 4	273	27.31	1.93	.117	3.78	7.07
			49		126	25.21	1.94	.173	3.80	7.70
	Average by year		50		273	26.84	2.04	.123	4.00	7.60
	Grand Average				399	26.65	2.17	.109	4.25	8.14
5	60–35– 5	S	49	3	48	26.04	1.51	.218	2.96	5.80
			50	3	75	25.85	1.46	.168	2.86	5.65
		Average		3	123	25.93	1.48	.133	2.90	11.18
5	60–35– 5	R	49	3	41	27.17	1.17	.183	2.29	4.31
			49	4	18	26.22	1.58	.373	3.10	6.03
			49	3 & 4	59	26.88	1.38	.180	2.70	5.13
			50	3	146	26.53	1.91	.158	3.74	7.20
		Average		3	187	26.67	1.80	.132	3.53	6.75
		Average		3 & 4	205	26.63	1.77	.124	3.47	6.65
			49		107	26.50	1.50	.145	2.94	5.66
	Average by year		50		221	26.30	1.79	.120	3.50	6.81
	Grand Average				328	27.37	1.70	.094	3.33	6.45

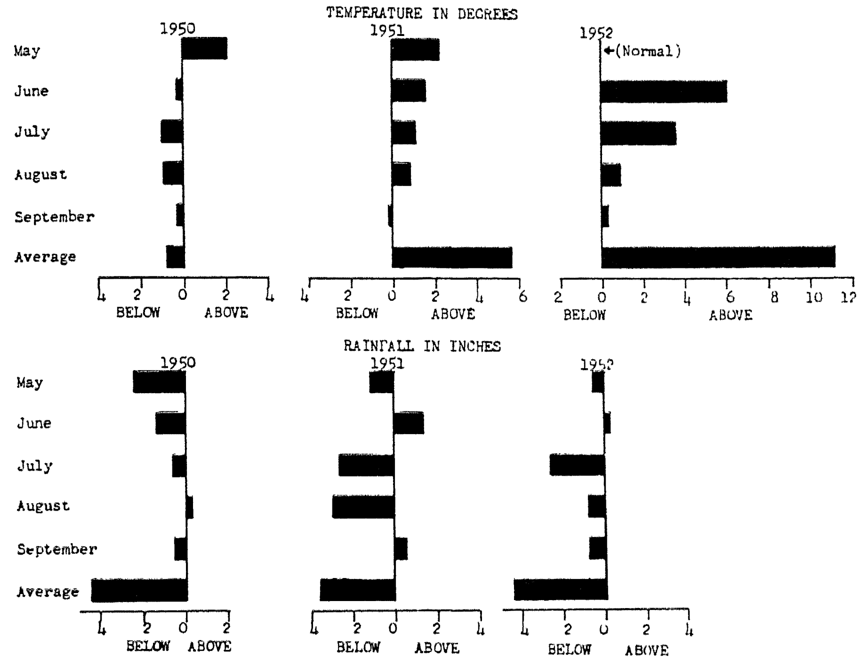
Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values X	Standard Deviation σ	Mean Square of Error σ_x	95% ± Values 1.96 σ	Coefficient of Variability V
6	60–25–15	S	49	3	46	26.15	2.34	.345	4.59	8.95
			50	3	65	25.97	1.69	.210	3.31	6.51
		Average		3	111	26.04	1.85	.176	3.63	7.10
6	60–25–15	R	49	3	24	27.33	1.14	.233	2.23	4.17
			50	3	87	26.46	1.48	.159	2.90	5.59
		Average		3	111	26.65	1.46	.138	2.86	5.48
	Average by year		49		70	26.56	1.88	.225	3.68	7.08
			50		152	26.25	1.59	.129	3.12	6.06
	Grand Average				222	26.35	1.68	.113	3.29	6.38
7	45–35–20	S	49	3	42	24.36	1.84	.284	3.61	7.55
			50	3	63	26.32	1.83	.230	3.59	6.95
		Average		3	105	25.53	2.07	.201	4.06	8.11
7	45–35–20	R	49	3	25	27.04	1.04	.208	2.04	3.85
			50	3	144	26.25	1.84	.153	3.61	7.01
			51	3	38	26.60	1.63	.265	3.19	6.13
		Average		3	207	26.41	1.58	.110	3.10	5.98
	Average by year		49		67	25.36	2 05	.250	4.02	8.08
			50		207	26.27	1.84	.128	3.61	7.00
			51		38	26.60	1.63	.265	3.19	6.13
	Grand Average				312	26.12	1.86	.105	3.64	7.12
8	36–65– 0	S	50	3	75	24.43	2.27	.262	4.45	9.29
		R	50	3	108	24.53	2.91	.280	5.70	11.86
			51	3	81	26.36	1.89	.210	3.70	7.17
		Average		3	189	25.31	2.56	.186	5.01	10.11
	Average by year		50		183	24.49	2.67	.197	5.23	10.90
			51		81	26.36	1.89	.210	3.70	7.17
	Grand Average				264	25.06	2.60	.160	5.10	10.38

Table C.—Statistical Analyses of Drained Weight Scores of Canned Tomatoes by Raw Product Composition, Variety (Stokesdale (S) and Rutgers (R), Year (1949, 1950 and 1951), and Process (Packed for Grade-4 and Mine Run-3)

Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values $\bar{X}$	Standard Deviation σ	Mean Square of Error $\sigma_{\bar{x}}$	95% $\pm$ Values 1.96 σ	Coefficient of Variability V
1	100–00– 0	S	49	3	72	17.12	2.24	.264	4.39	13.08
			50	3	31	18.06	1.66	.298	3.25	9.21
			51	3	29	16.72	1.95	.363	3.82	11.63
		Average		3	132	17.27	2.14	.186	4.19	12.37
1	100–00– 0	R	49	3	72	18.97	1.31	.154	2.57	6.90
			49	4	36	18.19	2.04	.340	4.00	11.21
			49	3 & 4	108	18.71	1.63	.157	3.19	8.71
			50	3	213	18.74	1.46	.100	2.86	7.79
			50	4	38	19.32	0.95	.154	1.86	4.91
			50	3 & 4	251	18.90	1.36	.086	2.66	7.20
			51	3	192	16.83	2.30	.166	4.50	13.64
		Average		3	477	18.05	2.08	.095	4.08	11.52
		Average		4	74	18.77	1.67	.194	3.27	8.90
		Average		3 & 4	551	18.14	2.04	.087	4.00	11.24
	Average by year		49		180	18 08	2.05	.153	4.02	13.55
	Average by year		50		282	18.82	1.45	.086	2 84	7.70
	Average by year		51		221	16 82	2.25	.515	4.41	13.38
	Grand Average				683	17.98	2.08	.080	4.08	11.57
2	90–10– 0	S	49	3	48	18.31	1.54	.223	3.02	8.43
			50	3	37	17.73	2.01	.330	3.94	11.33
		Average		3	85	18.06	1.78	.193	3.49	9.88
		R	49	3	66	19.54	0.94	.116	1.84	4.81
			50	3	179	18.93	1.67	.125	3.27	8.82
			50	4	36	19.69	6.17	.103	1.21	3.13
			50	3 & 4	215	19.06	1.62	.110	3.18	8.50
		Average		3	245	19.10	1.51	.100	3.08	8.22
		Average		3 & 4	281	19.17	1.50	.089	2.94	7.82
	Average by year		49		114	19.63	1.38	.129	2.70	7.25
	Average by year		50		252	18.86	1.74	.110	3.41	9.22
	Grand Average				366	18.92	1.63	.085	3.19	8.62
3	75–25– 0	S	49	3	48	18.23	1.54	.223	3.02	8.45
			50	3	71	17.50	1.81	.215	3.55	10.34
			51	3	25	15.96	2.23	.446	4.37	13.95
		Average		3	144	17.48	1.96	.163	3.84	11.21

Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values X	Standard Deviation σ	Mean Square of Error σ,	95 % Values 1.96 σ ±	Coefficient of Variability V
3	75–25– 0	R	49	3	42	19.57	0.87	.135	1.71	4.47
			49	4	18	18.56	1.71	.403	3.35	9.21
			49	3 & 4	60	19.27	1.28	.165	2.51	6.64
			50	3	174	18.86	1.47	.111	2.88	7.79
			50	4	38	18.13	1.20	.194	2.35	6.27
			50	3 & 4	212	18.91	1.43	.098	2.80	7.56
			51	3	117	17.33	1.91	.176	3.74	11.02
		Average		3	333	18.41	1.85	.101	3.63	10.05
		Average		4	56	18.95	1.41	.188	2.76	7.44
		Average		3 & 4	389	18.49	1.80	.091	3.53	9.73
	Average by year		49		108	18.81	1.49	.143	2.92	7.92
			50		283	18.56	1.65	.098	3.23	8.89
			51		142	17.09	2.16	.181	4.23	12.64
	Grand Average				533	18.24	1.90	.082	3.72	10.42
4	75–15–10	S	49	3	66	17.62	2.29	.282	4.49	12.99
			50	3	60	18.90	1.57	.203	3.08	8.31
		Average		3	126	18.23	2.08	.185	4.08	11.41
4	75–15–10	R	49	3	42	19.71	0.70	.107	1.36	3.53
			49	4	18	18.28	2.42	.571	4.74	13.24
			49	3 & 4	60	19.28	1.59	.205	3.12	8.25
			50	3	176	19.03	1.19	.089	2.33	6.25
			50	4	37	19.59	0.79	.130	1.54	4.02
			50	3 & 4	213	19.13	1.33	.091	2.61	6.95
		Average		3	218	19.16	1.32	.089	2.59	6.89
		Average		4	55	19.16	1.65	.222	3.23	8.61
		Average		3 & 4	273	19.16	1.39	.084	2.72	7.25
	Average by year		49		126	18.41	2.16	.192	4.23	11.73
			50		273	19.08	1.38	.084	2.70	7.23
	Grand Average				399	18.87	1.70	.085	3.33	9.01
5	60–35– 5	S	49	3	48	18.77	1.76	.244	3.45	9.38
			50	3	75	19 03	1.05	.121	2.00	5.52
		Average		3	123	18.93	1.48	.133	2.90	7.82
5	60–35– 5	R	49	3	41	19.58	0.77	.120	1.50	3.92
			49	4	18	17.83	2.61	.616	5.12	6.83
			49	3 & 4	59	19.05	1.77	.230	3.47	9.29
			50	3	146	19.20	1.15	.095	2.25	5.99
		Average		3	187	19.29	1.09	.080	2.14	5.65
		Average		3 & 4	205	19.16	1.36	.095	2.66	7.10
	Average by year		49		107	18.92	1.76	.170	3.45	9.30
			50		221	19.11	1.20	.081	2.35	6.28
	Grand Average				328	19.22	1.42	.078	2.78	7.39

Lot No.	Composition	Varieties	Year	Process	Can Count	Average Values $\bar{X}$	Standard Deviation σ	Mean Square of Error $\sigma_{\bar{x}}$	95% ± Values 1.96 σ	Coefficient of Variability V
6	60–25–15	S	49	3	46	18.15	1.82	.268	3.57	10.03
			50	3	65	18.57	1.27	.158	2.49	6.84
		Average		3	111	18.40	1.54	.146	3.02	8.37
6	60–25–15	R	49	3	24	19.04	1.24	.253	2.43	6.51
			50	3	87	19.32	1.21	.130	2.37	6.26
		Average		3	111	19.26	1.22	.116	2.39	6.33
	Average by year		49		70	18.45	1.69	.202	3.31	9.16
			50		152	19.00	1.29	.105	2.53	6.79
	Grand Average				222	18.83	1.40	.094	2.74	7.43
7	45–35–20	S	49	3	42	18.43	1.76	.272	3.45	9.55
			50	3	63	18.19	1.74	.219	3.41	9.56
		Average		3	105	18.28	1.75	.171	3.43	9.57
7	44–35–20	R	49	3	25	19.76	0.71	.142	1.39	3.40
			50	3	144	19.60	0.74	.064	1.52	3.92
			51	3	38	17.31	1.85	.300	3.63	10.69
		Average		3	207	19.20	1.38	.096	2.70	7.19
	Average by year		49		67	18.92	1.60	.196	3.14	8.46
			50		207	19.17	1.33	.092	2.61	6.94
			51		38	17.31	1.85	.300	3.63	10.69
	Grand Average				312	18.89	1.57	.089	3.08	8.31
8	36–65– 0	S	50	3	75	18.33	1.84	.212	3.61	10.04
		R	50	3	108	18.98	1.31	.126	2.57	6.90
			51	3	81	17.85	2.12	.236	4.16	11.88
		Average		3	189	18.50	1.78	.129	3.49	9.62
	Average by year		50		183	18.72	1.62	.120	3.18	8.65
			51		81	17.85	2.12	.236	4.16	11.88
	Grand Average				264	18.45	1.80	.111	3.53	9.76



Appendix Chart No. I.—Climatological Data—Temperature and Rainfall Deviation from Normal During the Growing Season for 1950, 1951 and 1952.